MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XX., PART 1.

FOOTE: GEOLOGY OF MADURA AND TINNEVELLY DISTRICTS.

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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

On the Geology of the Madura and Tinnevelly Districts, *by* R. Bruce Foote, F.G.S., *Deputy Superintendent, Geological Survey of India.*

CHAPTER I.

INTRODUCTORY.

Although only the eastern parts of the Madura and Tinnevelly districts have been actually surveyed, with the view to completing the examination of the fringe of sedimentary formations which borders the coast of the Indian Peninsula, yet enough is known about the unsurveyed parts of the two districts to admit of the preparation of a sketch of their geological features.

The topography of the districts is very simple, as they both form part of the tract lying between the water-parting along the axis of the Southern Ghâts and the Bay of Bengal. Except in the north-west part of Madura district, where the Palani mountains stretch to the north-eastward away from the main mass of the Southern Ghâts, the mountain tract belonging to the two districts is very narrow, much which was formerly considered British territory having been ceded by the boundary commission to appease the land hunger of the Travancore Government. Only two spurs worthy of note extend into the

Orography.

Spurs of the Southern Ghâts northern part.

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British territory. The first of these is the Vārshanād ridge which extends into the Āndipatti and Nagamalai hills, which latter die away in the plain a little to the west of Madura town. The second spur to be noted is the nameless mountain mass projecting into the Kambam valley and dividing the headwaters of the Suruli or Shurley-ār from those of the Vaigai (Vygay).[1]

Vārshanād spur. Subsidiary spurs.

The Vārshanād spur branches off from the high Puluvurangan or Kotay peak (6,617′), and throws off three subsidiary spurs to the eastward—the Pémalai (5,575′), west-north-west of Srivilliputur (Shevilputur); the Saddragiri (4,172′), some 15 miles to the north-east-by-north; and the Kudirai Malai (4,262′), further 15 miles to the northward of the last named spur. These side spurs are higher than many parts of the main spur.

Outlying hills.

To the north of the Vaigai river a small number of detached hill masses extend eastward from the Dindigul valley and may be regarded geologically as an extension of the gneissic beds forming the Palani mountains. The principal of these masses are the Sirumalai (4,454′), the Karuntha Malai, the Waggut Malai, the Alagiri, the Nattam hills, and the Prá Malai,—a group of hills remarkable chiefly for their terribly feverish and unhealthy climate.

Of the outlying hills to the south of the Vaigai. The most important are the Parayur hills in Tirumangulam Taluq (Madura). Further south in Tinnevelly district, the Periur hill (1,378′) near Sankaranainar Koil, the Vallanād hills (1,023′) east of Palamcotta and, in Nanguneri Taluq, the very conspicuous Suttu-pottai, a remarkable bare-topped rocky cone, some 1,200′ or 1,500′ high. The other hills shown in the Atlas sheets 62 and 63 are mostly mere low narrow rocky ridges of trifling importance topographically, and of but little more importance geologically considered.

[1] This mountain spur is shown in the Atlas sheet (No. 62) as a "high waving mountain overrun with an impenetrable forest," which forms a very marked contrast to the very thin forest which covers the ridges and slopes of the Varshanād spur.

The central and southern parts of the Southern Ghâts tract require but very brief mention here beyond their general influence on the climate of Tinnevelly District and the fact that they feed the sources of all the more important southern rivers.

The Southern Ghâts, central and southern parts.

Hydrology.—The hydrology of the two districts is as simple as the orography, as all the rivers flow to the east or south-east. The Varshalei or Manimutár, the Seruvayal or Up-ar (Salt river; Hoop-aur of sheet 80), and the Vaigai which drain the northern and central parts of Madura district flow into the Bay of Bengal through Palk's bay. The southern part of Madura district is drained by the Gond-ār, which debouches into the Gulf of Manaar.

Rivers in Madura district.

The drainage of Tinnevelly district is effected by the Vaippār in the north, the Tāmbraparni in the centre, and in the south by three small rivers—the Nát-ar or Kára-meni-ar, the Nambi-ar, and the Hanamanadi.

Rivers in Tinnevelly district.

Of the several rivers enumerated above only one, the Tāmbraparni, comes really under the influence of the south-west monsoon and obtains a steadily sustained supply of water during the continuance of the summer rains. The reason of this is that the Tāmbraparni, and to a lesser extent its main northern tributary, the Chittar, have their headwaters rising well within the limit of the area over which the rain clouds rest continuously. The positions occupied by the clouds during the south-west monsoon appear at first sight to be somewhat capricious, but they are doubtless in great measure due to currents of air caused by the peculiar configuration of the mountain masses, which mostly terminate eastward in very abrupt and precipitous scarps. The clouds, which cover the mountains, often for weeks together without lifting entirely, lie banked up along the water-shed, or extend but little to the eastward of it.

Water-supply of the Tāmbraparni.

Except in the case of the Tāmbraparni, unfortunately for the Madura and Tinnevelly plains, the watershed is mostly close to, or coincident with, the top of the eastern scarp; hence nearly the whole

of the very heavy rainfall is drained off into the sea or the backwaters of Cochin and Travancore, and forms powerful streams rushing through a wide tract of densely-wooded hill country, while on the east side of the mountains the rainfall is very scanty, and the rivers receive only occasional freshes which cannot be steadily depended on.

Position of watershed.

Thus the Vaigai, the principal river in Madura district, though it rises in a valley surrounded by high mountains covered in great part with dense forests, receives a very scanty and uncertain south-west monsoon supply, from the fact that the monsoon clouds do not proceed eastward beyond the watershed which coincides with the western and southern sides of the Kambam valley. The Vārshanād spur and the lofty Peyá Malai or Pémalai[1] at its southern end, though attaining an elevation of from 4,000 to 5,570 feet, are rainless as compared to the mountains a few miles only to the south-west. Further to the north the Palani mountains, though as nearly as possible equal in their average height to the more westerly mass of the Anai Malai (elephant mountains), receive a greatly smaller water-supply from the south-west monsoon. The chief rainfall in the Madura and Tinnevelly plains occurs during the north-east monsoon, and when this fails partially, as it not unfrequently does, the plains suffer from severe drought. The Tāmbraparni river has from time immemorial never failed in its water-supply, and two enormous crops of rice are raised every year in its most fertile valley. The Vaigai, though a considerably larger river, reckoning size by the area of drainage, can only ensure one crop per annum, the second crop frequently failing.

Water-supply of the Vaigai.

This untoward state of things would appear to be perfectly remediable by a great engineering work known in Madras as the Peria-ār project by which the

The Peria-ār project.

[1] The Pémalai, or devil mountain, as it is popularly called, should, according to Bishop Caldwell, the great Dravidian scholar, be rightly called Peyámalai, or *the rainless mountain*, a very suitable name, as it is often visible under a clear sky when Pulavurangan peak and the main mass of the mountains are completely hidden by the dense clouds of the south-west monsoon and deluged with rain.

water of the Peria-ār (which drains the great plateau south of the Kambam valley) would be brought into the head stream of the Vaigai. This grand scheme which has quite lately been sanctioned by Government will enable about 150,000 acres of land to be irrigated in addition to what is now supplied with water, and the whole to bear two wet crops every year. It is needless almost to say that no greater blessing could be conferred on the district than the carrying out of this project.

Fresh-water lakes.

A somewhat remarkable hydrological feature in South-East Tinnevelly is the existence of three or four small fresh-water lakes formed by the damming back of the local surface drainage by the great hills of red sand which form such conspicuous objects in that quarter. The most important of these lakes is that of Taruvai (Thurva) shown on the Atlas sheet (63) quite incorrectly as a tank with a bund on its northern, eastern, and southern sides. The water is retained simply by the accumulation of sand hills to the south, south-east, and north-east. In favourable seasons it forms a noble sheet of perfectly fresh-water, but when the monsoon fails it runs occasionally quite dry. I mention this fact on the authority of Bishop Caldwell, whose mission station, Edeyengudi (Idaiyarkudi, the shepherd's hut), lies about 4 miles to the south-west. There are two small lakes lying south-west of the Taruvai lake ; the more easterly of the two is not shown in sheet 63, but the western one is again erroneously shown as an artificial reservoir close to Sodi Kavalai (Shootee Coyvella, sheet 63). The true lake character of these basins and of two other ones to the northward of Taruvai lake seems to have been completely misunderstood by the topographical surveyors [1] who have mapped them as common tanks. Of these last two lakes the more southerly, sometimes called the little Taruvai lake, lies about a mile north of the large lake. The other lake lies on the north or left side of the Karameni-ar 3 miles further to the north-east. The waters of these lakes are remarkable for the

[1] The great Taruvai lake is shown on the half-inch map of the Madras Revenue Survey as a mere swamp, a yet far greater blunder than that of the old Topographical Surveyors.

enormous numbers of fresh-water mollusca, especially Melanias, they support.

Lagoons and back-waters (Kayals).

A number of lagoons occurs along the coast in both districts, but they are of no great size nor of much interest. The most southerly of these is the Kalampalli Taruvai which is formed by the belt of coast dunes extending from Manapada up to Tiruchendur. The water of this lagoon becomes highly brackish in the hot weather. The principal group of lagoons is that formed by the Tāmbraparni river on the seaward edge of its delta. These lagoons which are locally termed "Kayals" silt up as the delta extends eastward and new ones appear to form by the surf throwing up successive barriers of sand on which the prevailing winds pile up low dunes. The rate of silting up seems to be rather rapid during the present century judging by the greatly diminished size of the lagoons as shown in the Revenue Survey Map when compared with their appearance in the Atlas sheet (No. 80) which shows their dimensions at the time of the original Trigonometrical survey made about the year 1828. The water of some of these lagoons is sufficiently saline to be used for brine at several salt works. To the north of the Tāmbraparni delta are the lagoons of Taruvai Kulam (Thuroovancolum) and Veppilodai (Vapulaoda). The lagoons and creeks near the mouth of the Vaippar and to the south of Melmandai (Mailmuntha) have also decreased in size considerably by silting up. Along the Rāmnād coast the great tank shown in the map as extending westward from Valimukkam (Vaulimookum) is really a salt water lagoon which is connected with the sea at Valimukkam by a small tidal creek. The great lagoon north of Kilakarai (Keelacurray) is formed by inundations during heavy rains, as is also the lake-like reach of the Vaigai river to the east of Rāmnād town. The lagoon on the north side of Rameswaram island is quite brackish.

Climates of the Districts.

There is considerable similarity in the climates of Madura and Tinnevelly Districts, both being very dry and hot and both being affected by the same monsoons. Of the two districts Tinnevelly is the drier, as it gets less of the north-

east monsoon than does Madura. Except along a narrow tract close in to the foot of the ghāts and in certain places opposite to deep gaps in the mountain range, the south-west monsoon rains benefit neither district to any appreciable extent, except it be by giving rise to the formation in some seasons of severe local thunderstorms which are accompanied by very heavy rains.

According to the rainfall map of India given by Dr. Brandis,[1] the eastern part of Tinnevelly District is very dry, having an annual average of less than 30 inches; but in the western part of the district the narrow tract above referred which gets the benefit of the south-west monsoon rain, enjoys a considerably moister climate with over 30 inches of annual rainfall.

In Madura the dry part of the district lies in the centre (including the Tirumangalam, Madura and Melur Taluqs) and has a moister tract both on the west and the east; the former being a continuation of the moister zone along the foot of the mountains, the latter a tract of country running along the sea-board.

In neither district are the north-east monsoon or winter rains absolutely reliable, and if they fail, the most important dry crops and the wet crops under the rain-fed tanks cannot be raised and much distress ensues. The failure of the monsoon rains in one season is often followed by excessive rains and consequent extensive and destructive floods.

On the whole both districts are very badly clothed with wood. The formerly extensive forests have been recklessly felled, and it will require many years of very earnest conservancy to see the country properly tree-clad once again.

Schedule of geological formations.

The rocks recognised during the progress of the survey may for convenience of description be arranged as in the subjoined tabular statement :—

8. Soils and subaërial deposits.
7. Blown sands, red (teris); white (coast dunes).
6. Fluviatile and marine alluvia, Kankar deposits.
5. Sub-recent marine beds, limestones and grits. Upraised coal reefs.

[1] On the distribution of forests in India, by Dietrich Brandis, Ph. D., Inspector-General of Forests, Calcutta. Reprinted from the Transactions of the Scottish Arboricultural Society, 1873. Edinburgh. M. Farlane and Erskine.

4. Lateritic conglomerates, gravels and sands.
3. Gritty sandstones, (Cuddalore or Rajamandri beds, Conjevaram gravels).
2. Gondwána rocks (Jurassic) ?
1. Gneissic rocks.

Owing to the general flatness of the sea-board in many parts of the country nearly up to the foot of the mountains, the streams all flow in wide shallow valleys, and there is consequently a remarkable want of good sections of the rocks of all ages, —a condition of things which has necessarily rendered the working out of the several formations much more difficult and their correlation so much the less satisfactory.

Note regarding the map.

The whole gneissic area falling within the limits of the map accompanying this memoir has been shown in colour, though not entirely surveyed in detail; the tracts surveyed in detail being represented by a darker tint. The tracts not actually surveyed in detail are however not unknown; many of them are traversed by high mountains and hills, the obvious continuations of gneissic beds well known and carefully examined within the surveyed areas. The eastern scarps and spurs of the Sirumalai, the eastern spurs of the Palani mountains, and the bare scarps of the great Varshanād spur of the Southern Ghâts show innumerable exposures of rock, which even the untrained eye cannot help recognising as extensions of the known gneissic beds. Further south in Tinnevelly district, beginning with the great Saddaragiri spur, great part of the western side of the district was crossed by me in various traverses made during a visit paid to the south in 1869. The country around Srivilliputtur and thence south along the foot of the ghâts to Kuttalam (Courtallum) was traversed, also the line of country lying between Srivilliputtur and Kuttalam *viâ* Sankaranainarkoil. I made various trips among the mountains west and south of Kuttalam (Courtallum)—a traverse from that place to Palamcotta, visits to the upper valley of the Tāmbraparni at and above Papanasam, to Ambur and Shermadevi, to the Singampatti valley and falls, and lastly to Tirukurungudi (Tricknangoody) and up the mountains to the Asambu plateau. Although I recorded no geological observations made during this trip, I became sufficiently acquainted with a

very considerable section of the country, to form a conclusive opinion as to the gneissic age of the main mass of the rocks of which it is formed.

CHAPTER II.

PREVIOUS OBSERVERS.

Greenough's map.

But very little geological information had been collected about either of the two districts here described when the survey was taken up. Both districts had been represented in Greenough's geological map of India; and like all the other districts with regard to which the map has been tested, the representation was in many ways very far from a true one.

Dr. Muzzy.

Long lists of rocks and minerals observed in Madura district and collected by the Reverend Mr. Muzzy of the Madura American Mission were published in the catalogue of the Madras Museum in 1855. Unfortunately the lists are deficient in detailed information as to the localities of occurrence of many of the rarer minerals, so that they have not been traceable in the short time at my command. The rock specimens too are enumerated from a mineralogist's rather than a geologist's point of view, so that practically the lists are of very little use in explaining the structure of the country.

The District Manual.

The geological notes in Mr. Nelson's very able and interesting manual of the Madura District (which is unfortunately out of print) are nearly all based upon Mr. Muzzy's data.

Dr. Caldwell.

For Tinnevelly district generally even much less had been published than for Madura, and it was only for the extreme south-east corner that a short but interesting sketch, relating chiefly to the more recent deposits occurring there, had been published by the Revd. Robert Caldwell, LL.D., the eminent Dravidian scholar, now Missionary Bishop in Tinnevelly district. Dr.

Caldwell's paper described the triangular area enclosed between straight lines drawn east and south from Nangunneri to the sea. I have unfortunately been unable to obtain a copy of this paper, so can only speak of it from memory after reading it many years since. His paper was accompanied by a sketch map of the country described, on which most of the leading features are laid down very truthfully.

Lieut.-Col. Branfill.

Some interesting observations on the nature and the rate of movement of the teris or red blown sands as distinguished from the white or pale sands of the coast dunes were made and published by Lieutenant-Colonel B. R. Branfill, Deputy Superintendent, Trigonometrical Survey.

Some further information of important character[1] on the rate of movement of the teri sands were given by Lieutenant-Colonel B. R. Branfill in the general report of the Great Trigonometrical Survey for 1873-74, which will be referred to at length when describing those remarkable æolian formations.

A few geological notes are given in the District Manual of Tinnevelly by Mr. A. G. Stuart, C.S., but they are too brief to convey much information.[2]

CHAPTER III.

THE GNEISSIC ROCKS.

The relations of the various great band of crystalline rocks, which are met with over the tract of country lying westward of the belt of sedimentary rocks lying along the sea-board of Madura and Tinnevelly districts, have not yet been worked out fully, nor can they be even approximately settled till the flanks and summits of the Southern Ghâts

[1] Notes on the Tinnevelly District by Captain B. R. Branfill, Great Trigonometrical Survey of India, Dehra Doon, 1869.

An important note on the climate of South Tinnevelly by Dr. Caldwell forms an appendix to Captain Branfill's pamphlet.

[2] A Manual of the Tinnevelly District, compiled by A. J. Stuart. M.C.S., Madras, 1879.

have been examined, for the greater part of the low country occupied by gneissic rocks in South Madura and North Tinnevelly is covered with a wide spread deposit of black cotton soil (regur). The few isolated outcrops of the gneissic rocks met with are far from sufficient to allow of any correlation of even the great bands of granular quartz rocks which form such conspicuous hills and ridges around both Madura and Palamcotta. Nothing more can at present be said of their relationship than that it is possible that both sets of beds may represent one and the same series. The great regur spread which forms the cotton district of Tinnevelly divides the two metamorphic areas so thoroughly that they must be considered and described separately.

(a) *The metamorphic Area of Madura District.*

So far as examined at present the gneissic rocks in the Madura district may be divided into six groups—

6. The upper granular quartz rock—Allagiri group.
5. The upper granitoid gneiss—Melur group.
4. The middle granular quartz rock—Nagamalai group.
3. The middle granitoid gneiss—Sikandarmalai group.
2. The lower granular quartz rock—Kokulam group.
1. The lower granitoid gneiss—Tirumangalam group.

Lower granite gneiss, or Tirumangalam group.

1. The lower granitoid gneiss group, the lowest of this series, is the set of beds occurring in the great plain forming the Tirumangalam Taluq, which is bounded on the east by the lateritic and alluvial formations. The northern part of the Tirumangalam plain is largely covered with red soil, but south of Tirumangalam town, cotton soil (regur) is met with everywhere, and allows but little of the subrock to be seen. The prevalent form of rock is granite gneiss, important outcrops of which are seen to the north of Tirumangalam at Karadikal (Kurdykul), along the south side of the great Mulang Kulam (tank) and at Nellayur to the north-east. Again to the south-east and south outcrops of very typical granite gneiss are to be seen along the valley of the Gondār and to the south in the Chevvur Kotai hill. The other outcrops are less characteristically granitoid in character, the rocks seen being rather banded massive gneisses

than granite gneisses. The general dip of the rocks over the Tirumangalam plain is north-easterly, corresponding to that of the overlying granular quartz rock. The same prevalence of north-easterly dip is to be noted in the various outcrops of gneiss, which show through the regur plain to the south-eastward between the valleys of the Gondār and the Vaipār. The principal outcrops here noted will be referred to at length further on.

Lower granular quartz rock, or Kokulam group.

2. *The lower granular quartz rock group* forms a low rocky ridge, about 2 miles southward of the great Nagamalai ridge which makes so conspicuous a feature in the landscape around Madura city. I have named it after the village of Kokulam (Cokolum) which stands close to where the ridge is crossed by the high road from Tirumangalam to Sholavandan. This band of granular quartz rock, though of no great thickness, forms a very well marked ridge, traceable, despite some gaps, for many miles. To the north-westward it was observed maintaining its individuality and its parallelism to the Nagamalai for several miles, indeed as far as the eye could reach from the new high road crossing the Nagamalai from Sholāvandān to Tirumangalam. At a point about 2 miles north-west of the Sikandar Malai (Skanda Malai) the ridge trends southward and then eastward again and passes southward of the last named hill, and then after trending south-east for some 3 miles changes its strike to north-east by east, and after a couple of miles is lost under the alluvium of the Vaigai at a point 4 miles due south of Madura. Owing to the coarseness of the rock, which is a typical granular quartz rock, the dip of the bed is not easy to recognise close at hand, but when seen from a little distance the dip is perfectly obvious, indeed strikingly clear. The question of the continuation of this formation on the north bank of the Vaigai river will be referred to again further on when dealing with the overlying Nagamalai granular quartz series.

Middle granite gneiss, or Sikandar Malai group.

3. *The middle granitoid gneiss group.*—Immediately overlying the lowest granular quartz series is a well marked band of typical granite gneiss, especially well seen in the Sikandar Malai 3½ miles south-west of Madura. It shows

well also in a picturesque rocky hill north of Ambalathandi (of map) a village 4 miles west of Madura, and again in some low rocky hills 6 miles further to the north-west close to the Sholavandan-Tirumangalam road. It is largely quarried in the Sikandar Malai, the pinkish grey well-banded rock yielding a very handsome and durable building stone. The bedding is not distinctly seen except from a distance, but is very striking when viewed from the south-east.

Middle granular quartz rock, or Nagamalai group.

4. The middle granular quartz rock group forms the long and important ridge called the Nagamalai (already referred to several times), which for many miles forms the southern side of the Vaigai valley, but dies down under the alluvium 4 miles west-north-west of Madura city. The beds make a great curve south-eastward under the alluvium and re-appear in the Pasumalai (or cow hill), a low bare stony hill to the north of the Sikandar Malai. From these the beds strike east-south-east for 2 or 3 miles and then disappear under the alluvium. These beds were followed up north-westward to the point 20 miles distant from Madura at which the Nagamalai changes its course and trends east by north to west by south. Their further extension south-westward is not yet known geologically. The eastern extension beyond the Vaigai will be described further on. The dip of these extremely coarse granular beds is much obscured by excessive jointing, but it is unquestionably northerly or easterly according to the strike of the beds and at very high angles. Some of the basset edges at the east end of the Nagamalai are weathered into bold tors, many of which present considerable resemblance to buildings and are often mistaken for ruins by travellers along the railway. Except where the mass is much broken down by weather action, the ridges of this peculiar rock are remarkable for their extreme barrenness of vegetation of all kinds. Owing to their very light colour, which varies from extremely pale reddish-white to pale reddish, or yellowish-drab, they show conspicuously to great distances. To the south-east of Madura a group of beds of identical character, which can only be regarded as the easterly extension of the Nagamalai beds, appears on the

left or north bank of the Vaigai and is traceable for several miles further to the east-north-east up to the great rocks west-south-west of Trivadur where the central beds of the group have assumed a very granitoid appearance and contain much felspar. Whether the granular quartz formation dies out here or is merely hidden by superficial deposits and re-appears further to the eastward in the great granular quartz ridge of Vallamalai (Vullamalay, sheet 80) or whether the latter represents the lower granular quartz group (No. 2) are questions yet to be decided. If the latter view is the correct one, then the picturesque rocky Tirumalai (Sacred hill), 6 miles east-north-east of Vallamalai, and the Kunatur (Coonatoor) Trigonometrical Station hill, 10 miles west-south-west of Vallamalai hill station, represent the Sikandar Malai granite gneiss band.

The upper granite gneiss, or Melur group.

5. *The upper granitoid gneiss group* occupies the plain north-westward of the Trivadur Trigonometrical Station ridge and stretches away south-westward down to the alluvium of the Vagai and north-eastward under the alluvium of the Pálár and its tributaries, beyond which it re-appears and extends north-eastward past Tirumayam (Tirmium) to beyond the confines of the map illustrating this memoir.

Characteristics of scenery.

The special features of the granitoid rocks are very strikingly illustrated in many of the hills rising out of this area which show great beauty of form and colour in the noble rock masses they consist of.

View from Pramalai.

Two of the most striking views of this area were got from its nearly opposite extremities. The one is from the southern slope of the western part of Prāmalai (itself remarkable for a splendid scarp, facing south), as you look south-south-westward across the rich and varied palm groves of the Pālār valley which form an exquisite foreground to the scene. The mid distance is occupied by a well-wooded country out of which rise a very considerable number of beautiful rocky hills, several of them surmounted by enormous tors, the back ground being formed by the many picturesque peaks of the great Varshanād spur of the Southern Ghâts. The western side of

the picture is framed by the fine scarps of granular quartz rocks on the flank of the great Allagiri (Allagherry) hill which contrast strongly with the gentle seaward slope of the plains on the eastern side.

View from Perumāl Malai.

The per contra view, which is also very beautiful, though not quite so artistically perfect, is to be seen from the summit of the Perumāl Mallai ridge 5 miles west-south-west of Melur (Mailore) and 12 miles north-east of Madura, and is one which will well reward any geologist or sketcher for the trouble of climbing the ridge. In this view the most striking object is Shomagiri Drug hill ridge which is seen so foreshortened as to be nearly cupola-shaped, while from a spur which branches off to the south-westward rises an enormous tor standing boldly on a much slenderer pedestal. As seen from the plain immediately to the north of the hill, this tor assumes the shape of the head and neck of a beautiful child. I estimate the tor and pedestal at from 60 to 80 feet high. Shomagiri is seen flanked by two other fine granitoid masses, neither of which are shown in sheet 80, from which many other smaller hills are also omitted.

Shomagiri Drug and Tor.

Other hills.

A fine group of these is clustered round the Karrinkalgudi (Kurrungálgoody) station about 7 miles north of Melur (Mailore) close to the Madura-Trichinopoly road. The view is bounded to the north by the line of hills extending eastward from the Sirumalai and terminating in the bold and striking mass of Prāmalai.

To the east of Melur are two noteworthy hills, both of them shown on sheet 80 as Trigonometrical Stations, and both of them remarkable for their wild and picturesque rock scenery. The first, Sharangamalai, lies about a mile south-east of Melur, the second called Codathumputty on the map, but locally known as the Periotamalai lies some 7 miles further east and is the highest and most conspicuous point for many miles around. To the south-westward of the Permal Malai mentioned above are several picturesque groups of granitoid rocks leading up to the north end of the Anai Malai or "Elephant" hill, a bold and bare rocky ridge running nearly parallel with the Madura road for close upon 3 miles.

The Elephant hill.

The southern and higher end of the ridge shows, especially as seen from the south and south-east, a very remarkable resemblance to the upraised head of a great elephant, and this doubtless suggested the legend by which the crafty priests of the great temple at Madura explain the origin of this remarkable hill. According to this legend some deity hostile to the goddess Minakshi, the foundress and patroness of the great temple, sent an enormous demon elephant to destroy both the town and temple, but the powerful goddess prevented the intended evil by petrifying the monster. Similar legends have been invented with regard to the Nagamalai (Serpent hill) and Passumalai (cow hill) west and south of Madura (see page 13). In the former case the theriomorphic character of the hill would readily suggest the legend, but in the latter the form of the hill, from no point of view, suggests a resemblance to any animal, and the origin of the myth is by no means obvious.

Nagamalai, Passumalai.

The stratigraphy of the Anai Malai is not at all easy to make out, the bedding being indistinct and also very much contorted. The quartzo-felspathic-micaceous rock is of grey colour banded with pink laminæ. In part it assumes a "blotchy" or coarsely porphyritic structure, and at the northern end of the ridge the beds are to be seen contorted into an imperfect but acute angled anticlinal. A similar sharp contortion of the beds forming the Perumál Malai or Narasingampatti hill referred to above (page 15) has been followed by the intrusion of a short but thick granite vein which forms the crest of the highest part of the ridge.

6. The upper granular quartz rock group.—The relations of the upper granite gneiss group to the great beds of granular quartz rock forming the bold scarp of the Allagiri hill could not be made out quite satisfactorily by the examination of the country close to Allagiri temple. The granite gneiss there appears to dip under the granular quartz rock, and if such is really the case and the succession be not disturbed by any inversion, then the Allagiri granular quartz rock must be grouped as a third or upper series of its kind as I have done. It is possible, however, that the Allagiri beds are really inverted beds, but on this point the evi-

Relations of the Melur and Allagiri groups.

dence of the north-east and south-west extensions of these beds disagrees; the north-east beds seem to dip eastward under the upper granite gneiss series as seen to the north of Kotampatti (Cotaumputty), but the southern extension dips north-westerly. Unfortunately time did not admit of my following up the extension beyond the south end of the Allagiri mass and working out its relation to the great gneissic masses forming the Waggat Malai and the Serumalai. I feel strongly persuaded, however, that the Allagiri granular quartz beds are a *bonâ fide* higher lying group, and will, when an exhaustive survey of that region is made, be found to overlie the granitoid gneiss beds forming the western side of the Serumalai, which beds are really extensions of the upper granite gneiss series of the Melur-Madura plain, the beds of which have trended round on the north side of the Vaigai valley. The rocks overlying the Allagiri beds I am not as yet acquainted with.

Granular quartz rock at Ammanayakanur.

In the south-western corner of the space which lies between the northern part of the Nagamalai and the south-western part of the Serumalai is a great show of granular quartz rock well exposed in strongly curved beds. These are well seen in the low ridge west of the railway station at Ammanayakanur (Ammanaikoor) which extends northward into the much higher Reshmullay Trigonometrical Station hill and south-westward into the Pulianattam (Poolianutthum) hills; the north-westerly extension of the granular quartz beds beyond the two last named hills has not as yet been worked out. The relation of these beds with another rather important outcrop of granular quartz rock 3 miles to the south-east at Ramrajpuram is obscured by the intervening spread of the Vagai alluvium. The extension of the beds seen in the latter outcrop is also speedily lost sight of to the eastward under the superficial deposits.

At Ramrajpuram.

The broad belt of granite gneiss which forms the mass of the Serumalai belongs doubtless to the Melur or third group of that variety of the gneissic rocks. Unfortunately want of time prevented my examining that very hilly tract; the westward extension of the Allagiri granular

quartz group was therefore not followed up, nor could it be traced by the eye for any distance as in the Allagiri itself, where it is visible for many miles.

Gneiss rocks in South Madura not divisible into groups.

The southern part of the gneissic area in Madura district cannot be divided into groups owing to the great extent to which its surface is obscured by superficial deposits, especially by wide spreads of regur, or cotton soil. These latter are to be met with all over the southern half of the Tirumangalam taluq and over the south-western part of the Rámnád zemindary. By far the greater number of outcrops noted were of granitoid gneiss. But it would not be fair to infer from this that schistose varieties of gneiss are not represented in due proportion; the fact being that only the highest points of the different outcrops are as a rule exposed above the superficial deposits, and that the harder granitoid beds show more prominent basset edges than the schistose beds. Very few outcrops of any kind are seen along the line of railway, or the old trunk road, to the south-ward of Tirumangalam, the spread of regur being very thick and un-broken. The outcrops most worthy of note along this line are the Chevvur Kotai hill 6 miles south of Tirumangalam, and the Kalligudi (Cullygody) hillocks 2½ miles west of the railway station of that name, both of granitoid gneiss.

Outcrops south of Tirumangalam.

Kalligudi outcrop.

In the latter case the pale greyish or pinkish-white quartzo-felspathic rock, banded with laminæ consisting mainly of rather pale red or pink garnets of small size with a few spangles of mica, strongly resembles the Cape Comorin rock. The rock is one of great beauty, especially when freshly quarried. At the time of my visit quarrying had been carried on largely, and fresh surfaces of many square yards in extent showed the lamination of the gneiss in very pleasing undulating patterns. The bedding strikes generally nearly west and east, and has a southerly dip of from 60° to 80°. The outcrops form a small group of low rocky hills to the west of the village of Kalligudi (Cullygoody) and about 3 miles westward of the South Indian Railway Station of that name.

About 6 miles north-east-by-east of Kalligudi station at the village of Tirumal is a broad (apparently double) band of coarse white crystalline limestone which may be traced for nearly 2 miles to the eastward, associated with much inter-bedded tremolite. Much of the surface of the bed has been quarried away, and what remains is not well seen, as the outcrop is very low and much obscured by the local swampy alluvium under the great tank. The dip of the bed (or beds) is doubtful, but in another bed of white crystalline limestone, which is to be seen at the north end of the great tank, ¾ mile to the north-west of Tirumal, the dip is distinctly southward, but at a very high angle. This bed which is only seen for a distance of 30 or 40 yards is fully 30 feet thick, and has a very coarse crystalline (spathose) texture like the Tirumal beds. Two small beds of crystalline limestone with associated tremolite occur a little to the westward of the village of Kok-kulam (Kokolum), a mile to the north-east of the last named limestone outcrop. The limestone is white and highly charged with granules of pale greenish or yellowish-grey coccolite. Two small beds of tremolite rock enclosing many nests of calcspar occur one in the bottom of the tank west of the Tirumal; the other to the north of the village Suddumbakulam on the left bank of the Gondár.

Crystalline limestone at Tirumal.

Crystalline limestone at Kok-kulam.

To the northward of this band of limestones comes a band of granite gneiss which may be reckoned as belonging to the lower granitoid gneiss (No. 1, page 11) of the Madura country. Unfortunately its relations to the more southerly beds of undetermined horizon could not be made out as the rocks were not seen in any juxta-position. Turning southward again along the high road from Madura to Ettiapuram and Tutikorin a good section of very white garnetiferous gneiss (strongly resembling many of the beds near Cape Comorin) crossing the Shevery Kotai-Ár at the ford south of Vakangoondoo.

A band of very typical granitoid gneiss may be traced from the valley of the Shevery Kotai-Ár at Shoilputty south-eastward close down to Tirushulai (Tiru-

Band of granite gneiss west of Tirushulai.

chooly). It is well exposed in the quarries close to Shoilputty, where the rock is of a fine-grained-dense variety of mauvey-pink colour, showing the bedding only where freshly broken. The rock is also well seen at Moonooroopoo rock (where it is of a dull reddish-brown colour), and at the Paraikulam rocks west of the Tirushulai tank. At the latter place the rock which is slightly hornblendic is well bedded, the laminæ being of rich pink and grey colours. The dip of the rock is westward in all these three outcrops.

Aruppukotai beds.

About 5 miles west of Tirushulai in and north of the village of Palaiyampatti (Paulayemputty) is a considerable show of rich red granite gneiss beds which would appear from their mineral similarity to be extensions of a very similar rock which forms the small rocky hill west of Aruppukotai (Arpoocotay) 2 miles to the south-south-west. This red rock is very largely quarried and yields a remarkably handsome stone which is in great repute in that region. Here also the beds have more or less easterly dip.

Serpentinous rock at Kovilpatti.

North-westward of this band of granite gneiss and separated from it by an intervening spread of cotton soil from 3 to 5 miles across is a tract of strongly banded gneiss intermediate in texture between granite gneiss and typical schistose gneiss which is particularly well seen at and to the south-west of Mallakanur (Mullakenur) 5 miles east-by-north of Virudupatti. Micaceous beds predominate here as generally throughout the Madura and Tinnevelly gneiss region, but hornblendic beds are also met with, while near Kovilpatti (Covilputty) a mile to the eastward a bed of decomposed serpentinous rock was observed. Unfortunately this serpentinous bed is exposed only in an inaccessible section in the side of a well and could not be examined closely. About 4 miles south-west of Makallanur and a little south of the village of Palavanattam (Kylassapooram of map) a large quantity of debris of a very coarse-grained greyish-white crystalline limestone is to be seen scattered over the surface and rolled in the bed of a small water-course. I was unsuccessful in tracing the outcrop from which this limestone debris was derived.

Kotaiparai Hill.

About 4 miles south of Palavanattam lies a small hill of bare rock rising on the top of the watershed between the valleys of the Virudupatti and Shenkotai rivers. This hill which is known as the Kotaiparai (Koteaupauræ Trigonometrical Station) is remarkable because consisting of dark hornblendic granite gneiss which is a very rare rock in this quarter. It rises out of the middle of a great and unbroken spread of cotton soil.

A great many outcrops of banded granite gneiss of no special beauty or noteworthy colour are to be seen on the high ground at and east and south-east of the village of Kalurani (Kulloornee) 4 miles south-east of Aruppukotai. To the south of Aruppukotai, close to Vala Vangal (Shevandapuram of map), is a show of very perfectly banded granite gneiss, both micaceous and hornblendic, striking north-west to south-east in almost vertical beds.

Pantalagudi crystalline limestone beds.

Four or 5 miles further south of Shevandapuram and a mile south of Pantalagudi (Punthullagoody) the high road cuts across a very large and important bed of crystalline limestone which I traced north-west-by-north for upwards of 3 miles cropping up through the thick cotton soil which covers nearly the whole surface in that quarter. The thickness of the great bed is not easy to ascertain, owing to the extent to which it is obscured by the cotton soil. I paced it at several points where best seen, and found it to average about 50 yards, the narrowest part being 37 and the widest 73. The limestone is generally of very coarse grain, so much so as in parts really to deserve the appellation of calcspar rather than crystalline limestone. This is more especially the case at the southern end where the predominant colour is pale grey or white. In the northern part of the bed its eastern or upper part is reddish or pink in colour and rather close grained. The dip where best seen at the southern end is from 65° to 70° north-easterly. The only included accidental minerals noted were occasional small granules of pale coccolite and spangles of graphite. About ¾ of a mile west of the northern end of the great bed is a small outcrop of white crystalline limestone

belonging to a smaller bed having a parallel course. A sufficient prolongation of these beds would connect them very probably with the beds from whence was derived the very similar coarse quasi-spathose debris noticed in considerable quantity at Palavanattam (Kylassapooram) which was referred to at page 20.

Two instances of gneissic rocks cropping out from among the lateritic and alluvial beds at a considerable distance from the main gneissic mass require notice. The one occurs below the western scarp of the Sivaganga laterite tract at and north of Mana Madura; the other along the south-western side of the Muddu Kankulam laterite tract (*see* page 49) immediately east of Kamudi (Kaumoody). In the latter the gneiss is a form (not seen elsewhere in that region) intermediate in structure between a rather ferruginous granular rock and a coarse quartz hæmatitic schist. The beds form a low ridge on which stands the old Kamudi fort. The rock which is of a purple-grey colour dips 45°—50° east-by-north.

(*b*) *The metamorphic Area in Tinnevelly District.*

The northern part of Tinnevelly district is so extensively and thickly covered with cotton soil that outcrops of the underlying rocks are in many places of very infrequent occurrence. It is particularly the case along the line of the railway and the old Tinnevelly-Madura high-road which run closely parallel to each other for the first 15 miles after entering the Satur taluq. Beginning close north of the town of Virudupatti we find a few small rounded masses of granite gneiss showing up through the cotton soil. Four miles south of Virudupatti the high road crosses a gentle rise from which the general pall of cotton soil has been removed by denudation and a considerable band of granular quartz rock beds revealed. The exposure is, however, too obscure to show much of the real position of the beds. The strike of the rising ground is east to west, but the form of the ground gave the idea that the real disposition of the beds was in form of an anticlinal ellipse, the eastern end of which dips under the alluvium of the Virudupatti river. To the southward of this granular quartz ridge numerous traces of the existence of beds of crystalline

limestone are seen along the high road in ditches and water-courses in the shape of large quantities of debris. *The limestone* is of extremely coarse grain and highly spathose in appearance. *The limestone* is of white colour. The country is, as already mentioned, very thickly covered with cotton soil, and I did not, during the cursory examination which alone I was able to bestow upon that particular tract, happen to light upon any outcrop of this rock in this neighbourhood.

Kolarpatti outcrop.

A few important outcrops of granite gneiss were observed further south in the valleys of the Virudupatti river and of the Vaippár, notably a considerable group of low rocky masses on the left bank of the former river a little below its junction with the Korai-Ár and opposite to the village of Kolarpatti (Colaurputty). Another considerable outcrop of banded granite gneiss occurs at the junction of the Virudupatti river with the Vaippár. Considerable exposures of typical granite gneiss, all more or less approximating in colour to the typical Cope Comorin gneiss, may be seen in the bed of the Vaippár at Kolapatti 2 miles east of Satur. Another noteworthy outcrop of similar highly garnetiferous banded granite gneiss occurs in the Waddakarai (Wudducurra) hill 4 miles south of that town and close to the South Indian Railway. The hill is a bare rock which is rapidly being quarried away for railway purposes. The lamination or bedding which is beautifully distinct strikes east-north-east to west-south-west (a very prevalent strike in these regions), while the dip measures 60°—65° north-north-west. The hill which was formerly a station of the Trigonometrical Survey rises very abruptly out of a vast plain of cotton soil.

Waddakarai hill.

Outcrops east of the Vaippár.

On the left side of the Vaippár valley the same wide spreads of cotton soil prevail and allow of but very few outcrops being seen. The most interesting of those noted was a bed of very handsome pink and pinkish-white crystalline limestone seen to the east of Shenkotai (Shencotta) 6 miles south of the great Pantalagudi limestone bed. The Shenkotai bed is exposed in the easterly off-flow channel of

Shenkotai limestones.

the great tank east of the village. It is fully 20 feet thick, but exposed only for a few yards distance in the bank of the channel. The limestone occurs intercalated with dark green hornblendic beds which contain numerous laminæ of pink calcspar. From its course (north-west-by-north to south-east-by-south) and its easterly dip this bed would appear to belong to the same series as the Pantalagudi beds. To the same series belongs also, to all appearance, the coarse reddish semi-granitoid gneiss seen at and north of Nagalapuram (Naugalapooram).

The most southerly outcrops in the gneissic area east of the Vaippár are a black hornblendo-micaceous gneiss at Kodangeputty and a show of granular quartz rock at Bommayapuram which is exposed only in the roadside ballast pits. Some connection will probably be traced eventually between this and the broad belt of granular quartz rock which rises out of the great cotton soil plain to the north of Ettiapooram (Etteyaupoórum) and forms the Minachipuram and Lyungumpatti hills which join the Kovilpatti ridge. This ridge trends south for several miles parallel with the railway, and then strikes south-eastward for fully 12 miles, when it again turns south, but after a course of some 3½ miles further again trends south-east and appears to curve round and form the southern end of an elliptical synclinal basin, the eastern limb of which runs northward through the taluq-town of Ottapiddaram and disappears some 4 miles further on under a great spread of regur. Several ridges of granular quartz rock are to be seen at some distance to the west of the railway between Kovilpatti station and the Maniachi junction, while two or three small granite gneiss hills rising out of the cotton soil plain to the north of Kaddambur station show the granular quartz rock to be here also interstratified with granite gneiss.

Bommayapuram granular quartz rock.

Kovilpatti granular quartz band.

The relations of several detached and isolated outcrops of granular quartz rock occurring south of the Ottapidaram-Kovilpatti band such as that lying west of Kil-Maniachi village (about a mile south-west of the

Outcrops of granular quartz rock south of Ottapiddaram.

railway junction) or the band exposed as Timmarajapuram 3 miles south-south-west of Meltattaparai Railway Station are doubtful. So also are those of low granular quartz ridge lying 1½ miles north-east of Sivaliperri (Shevvelperry) which disappears northward under the alluvium of the Chittar. To the same category belong the outcrops forming the low hills to the west and south-east of Pudukotai (11 miles south-west of Tutikorin). It was found equally impossible to correlate these outlying outcrops with the great band of granular quartz rock forming the Vallanād ridge. The granular quartz rock here forms a great anticlinal curve, the eastern limit of which extends south-east towards Sevalai (Shenvetta) and Verankulam in the Tambraparni delta under which it disappears. To the south the western limb of the Vallanād anticlinal curve re-appears south of the river in a gneiss inlier 3 miles west of Pudugudi, but its further extension is lost sight of under a sandy plain. It is possible that the granular quartz rock bed forming the hills west of Vallanād ridge may form part of the anticlinal curve and have its eastern limb represented by the quartzite ridge which disappears under the alluvium of the delta to the north-west of Perunkulam (Perungcolum).

Vallanád beds.

The great double band of granular quartz rock south of Palamcotta forms several very well-marked and conspicuous rocky ridges as the Rettiapatti (Ruttiaputty) hill, the Sevandipatti (Shaminthaputty), and the Kistnapuram and Thurva ridges at the eastern and western extremities of the band. The western extremity of the southern of these two bands of granular quartz rock crosses the Tambraparni 3 miles south of Tinnevelly town, then rises into the Sangani (Shenganny) Trigonometrical Station hill, beyond which it continues westward for some distance into the unsurveyed tract.

Palamcotta granular quartz rock beds.

The northern of the two bands which form the Rettiapatti ridge dies down suddenly close to Rettiapatti village and cannot be traced any further westward; it is probably cut off by a fault, but this cannot be positively proven owing to

Rettiaputty ridge.

the thickness of the local superficial deposits. At the eastern end of the ridge also the bed cannot be followed up for a considerable distance, but it apparently re-appears in the low but well-marked ridge running north-east by north from Kistnapuram to Pareikulam. The dip of the granular quartz rock in both ridges is northerly. The eastern extension of the Sevandipuram-Sangani band is also obscure and doubtful; the probability is, however, that it thins out greatly and is represented in a small ridgy outcrop running north-east-by-north parallel with the Kistnapuram ridge about a mile to the eastward. This may be the true correlation of the beds, but a gap some 2 miles in length exists between the Sevandipatti hill and the north-easterly ridge, and it is not impossible the real extension eastward of the band might be found in the Karunkulam hill which forms an inlier of granular quartz rock rising out of the alluvial flat of the Tambraparni.

Sevandipuram-Sangani band.

Another very important show of granular quartz rock is to be studied to great advantage in the Melpattam (Maillapantam) Trigonometrical Station hill $2\frac{1}{2}$ miles north-east of Palamcotta. The rocks here form a large and very well marked horse-shoe curve open to the north. The western arm of the horse-shoe seems to re-appear north of the alluvium of the Tambraparni valley and to join the great band of granular quartz rock forming the Taliyuttu-Pottai ridge. The actual junction of these beds has, however, not as yet been traced out.

Melpattam granular quartz rock ridges.

A moderately large well marked bed of granular quartz rock lies close in to the military cantonment at Palamcotta. This bed runs nearly due eastward for about $2\frac{1}{2}$ miles when it is lost sight of under a great spread of gritty red soil.

Granular quartz rock band east of Palamcotta cantonment.

The most southerly outcrop of the granular quartz rock is the south-westerly extremity of the great Vallanād hill band close to the village of Viralaperi. The gneiss region lying southward of this point shows an absolute predomi-

South Vallanad granular quartz rock beds.

nance of granitoid forms of crystalline rocks. As already mentioned when describing the granular quartz rock outcrops in the neighbourhood of Madura, they form from their bright colours and great bareness very conspicuous features in the landscape, especially along the railway from Kovilpatti down to Tinnevelly and all round Palamcotta. The greatest show is made in the rocky ridge south of Kovilpatti, which culminates in the Kurumalai (Trigonometrical Station) a picturesque hill 821 feet high, and in the Vallanād hills (see ante, page 25) which attain a height of 1,023 feet (1,052 feet according to the Madras Revenue Survey map). The thickness of the beds here exposed is very great, and may be estimated at fully 2,000 feet, but the section is not clear enough to allow of actual measurement. To the south of the Trigonometrical Station peak the dip, where distinct enough to be measurable, is from 65° to 70° westward, and the rock approaches in appearance to a glassy quartzite, from which it only differs in the coarseness of the grain, which feature however is much less conspicuous here than in many other outcrops. The prevalent colour here of the least weathered parts of the rock is a dull pale pinkish-brown, elsewhere whitish-drab or very pale reddish-white are the commonest colours. Pale salmon colour was noted in the summit bed of the Pasu Malai near Madura and in the ridge north-north-west of Kotampatti Travellers' Bungalow 15 miles north of Melur and 34 miles from Madura.

Vallanād section.

Texture and colour of the rock.

Owing to the economically useless character of this rock it is hardly ever quarried to sufficient depth to show its real texture and composition. In most outcrops the only mineral seen to occur in the minute spaces between the different quartz granules is an earthy (? decomposing) hæmatite. It was nowhere so well seen as in the bed north of Kotampatti, just referred to. This is often absent having either been weathered out or having never existed in those spaces. In some examples the rock shows small cavities filled with white or pale pink decomposed felspar, and in one case I found traces of much decomposed greenish hornblende. This was in stone

Mineral character.

brought apparently from the lowest granular quartz band to the north of Tirumangalam in Madura district. In another case in the south of Trichinopoly district traces of dark blackish-green mica in extremely small scales could be made out. Although the bedded character of the rock is generally very obvious, these quartzose beds have often been mistaken for large reefs of vein quartz and have given rise to many hopes of their turning out auriferous. In the proximity of these beds the general surface of the country is often largely covered with very characteristic reddish angular debris. Such is very markedly the case all round Palamcotta. Beds of similar character were noted in Northern Travancore by my colleague, Dr. King, and in Southern Travancore by myself.

Intercalation with granite gneiss band.

As in the Madura country, the Tinnevelly granular quartz bands are always found to be under and overlaid by bands of various thickness of typical granitoid gneiss, which owing to its greater susceptibility to weather action has almost everywhere been more extensively denuded, and is therefore very frequently marked by the superficial deposits. Outcrops of the granite gneiss are to be seen at Paraipatti (Pauraeputty) 2 miles north of the Kadambur Railway Station and to the west of Ottapidaaram within the apex of the triangle described by the granular quartz beds (*vide* map). Granite gneiss beds are exposed also in several places, south-east and south-west of the apex of the triangle just named, *e.g.* at Dalavaipuram (Thullavaupoorum).

Cape Comorin type of granitoid gneiss.

As already stated above, the gneiss of the region south of the Sangani-Sevandipatti and Vallanad granular quartz bands is pre-eminently granitoid. The most noteworthy type among the granitoid gneiss is a pale quartzo-felspathic banded rock with a small quantity of black mica (very rarely of hornblende and very numerous small pale red or pink garnets. From its having been first noted near Cape Comorin where it occurs very largely, I designated it the Cape Comorin type. Granitoid gneiss of this type is also very common in the tract south of Tirumangalam intermediate between the Madura and Tinnevelly granular quartz bands. Striking examples of

this often very beautiful rock are to be seen in the low hills west of Kalligudi Chuttrum Railway Station again to the north-east and east of Satur and in the Waddakarai hill south of that town (see page 23). At the first and last of these localities the rock can be seen to great advantage as extensive quarries have exposed considerable surfaces of unweathered gneiss. The distinctness of the banding and the bright colours of the rock—white, grey, and pink—produce an effect which is very pleasing to the eye.

Gneissic outcrops in South Tinnevelly.

Of the outcrops of gneiss in the south of Tinnevelly not very much can be said, for except close in to the mountains they are neither numerous nor important. By far the greater number show beds of well-banded quartzo-felspathic gneiss, abounding in small red or pink garnets, of the Cape Comorin type in fact, the strike being west-north-west to east-south-east. They form part of several synclinal and anticlinal foldings whose westerly extensions may be traced in the Ghâts, while their eastern extensions disappear under the broad band of more recent rocks which fringes the south-eastern littoral. Many of the larger outcrops may be correlated with the great synclinal ellipse embracing the southern half of Travancore and having its eastern focus in or near the Mahendragiri, the most southerly of the great peaks of the Southern Ghâts, a noble mountain attaining a height of 5,419 feet.

Great synclinal ellipse of Mahendragiri.

Singikulam outcrop.

The most noteworthy of the outcrops are the following :—(*a*) The Singikulam (Shingacolum) Pottai, a low but boldly rocky ridge of typical granite gneiss 10 miles south-south-west of Palamcotta. Its western extension crosses the Pachiyar (Puchaur) and forms some considerable rocky hills which appear to be connected with the beautiful Kolunduma Malai, one of the finest isolated masses in Tinnevelly district. The bedded structure of the gneiss on a great scale is admirably displayed in that fine hill which rises high over the surrounding country. A number of picturesque rocks and low bare hills of granite gneiss diversify the country some miles south-west and south of the Singikulam ridge,

and a couple of miles further south rise the several fine sharp-peaked hills forming the Narayanan Pottai ridge north of the road leading from Nanganeri to Kalkad (Calcaud). Narayanan Pottai, which must be at least 1,000 feet high, consists of a garnetiferous granite gneiss offering no special characters. The beds have a well marked southerly dip. Outcrops of the easterly extension of this series are to be seen 4 miles to the east-south-east of Nanganeri at Pottaiyadi, and 6 miles further on to the north and east at Vijayanarayanam (Visionaurainum) where the strike of the beds trends from east-south-east to east-north-east.

Narayanan Pottai outcrop.

About 2½ miles south of Nanganeri rises another ridge parallel with the last named. In the hill forming the western part of the ridge a series of typical "Cape Comorin" gneiss beds is exposed; the beds lying at remarkably low angles only from 10° to 20° south. As seen from the north, the bedding is so wonderfully clear and well preserved that it is very difficult to realise that one is looking at beds of a highly metamorphic rock. The easterly extension of the ridge shows an underlying set of highly granitoid beds in which the bedding is by no means strikingly developed. To the south of the Tirukurungudi (Tricknaungoody) river and west of the high road from Nanganeri to Panagudi (Punnaugoody) is a remarkable cluster of bare rocky hills of banded granite gneiss, the most south-westerly of which the Suttu Pottai, or Tirukurungudi hill, forms a noble conical mass rising from 1,200 to 1,500 feet above the plain. It is the most nearly perfect cone I have ever seen in crystalline rocks, and to all appearance quite inaccessible; a legend exists, however, that it was once scaled by a young native at the instigation of the Trigonometrical Survey people, who followed him up by means of ropes and established a Trigonometrical Station on the top. No remains of the station are now visible from below. The bedded character of the gneiss is made visible by bands of different colour crossing the bare rocky base of the cone on the northern side. Good shows of similar banded

Outcrops south of Nanganeri.

Tirukurungudi hills.

gneiss are to be seen in the rocky hills at Valliyur (Vullioor) and Teka Valliur (Theeka Vullioor) and at Kallikulam (Kullycolum) 4 miles to the east-south-east. The dip of the bedding in the Suttu Pottai appears to be southerly, and in the Valliur hill a little to the south it appears to have changed and become northerly. These dips agree well with the requirements of the easterly extension of the great synclinal ellipse spoken of above (page 29). Further south still the general dip of the rocks is northerly as it should be to suit the ellipse theory. The predominant form of gneiss in the south is a quartzo-felspatho-micaceous rock, but several outcrops of hornblendic gneiss were also noticed, *e.g.*, the Manpottai (Great Trigonometrical Station) 4 miles south of Panagudi (Punnaugoody), and others at Erukanturai (Irkunthoora) 7 miles to the south-east, and again at the north of the Viziapatti (Vissiavethee) creek. One of the hornblendic beds at this place contains wollastonite, with coccolite and calcspar. The hornblendic gneiss here runs out into the sea forming a small reef visible for some hundred yards at low water. At several other places the gneiss rocks jut out a little distance into the sea, *e.g.*, at Kuttankuli (Kothaungculle) 2 miles to the north-east, at Idindankarai (Iddingekurra) 1 mile to the south-west. Rather more than a mile to the west of the latter place a narrow strip of granite gneiss shows for about 3 miles along the coast. Its western end is due south of the Kudankulam Trigonometrical Observatory which is the southern extremity of the Cape Comorin base line.

Valliur outcrops.

Manpottai and Erukanturai hornblendic beds.

Viziapatti hornblendic granite gneiss.

There appears to be no connection between these gneissic beds and the reefs which stretch along this coast, as the latter always run parallel with the coast line from which extensions of the gneiss beds would diverge very widely. These reefs are partly ridges of marine sandstone now in course of formation, partly coral fringing reefs, and will be separately treated of further on.

No connection between gneiss ridges and existing coast reefs.

A very remarkable feature in the gneissic region south of Trichinopoly

is the almost entire absence of intrusions of trappean rocks which are so common in more northern parts. Only three trappean instrusions came under my notice in the south, of which only two were of trap rocks *in situ*. These were a tiny dyke of diorite a few inches thick and a few yards long running nearly due north and south exposed in the dry bed of the Tumalpadi tank south of Tirushulai in Rāmnād zemindari. The second case is in the narrow coast strip of gneiss at the south end of the Cape Comorin base line. Here a number of large weathered blocks of diorite are scattered about among the blown sand hillocks. They looked as if they had been much surf-worn and were probably derived from the marine beds, the remains of which stretch away to the northward. The third case did not occur actually within the limits of the present Memoir, but in the Travancore country a few miles to the westward. Here a very narrow sharp cut dyke of tachylite is seen cutting through massive granite gneiss. The dyke which is exposed for a distance of between 100 and 150 feet in length is only 4 or 5 inches thick. It has weathered somewhat faster than the granite gneiss it cuts through, and is therefore rather sunk, and forms a small channel across the face of the rock.

Absence of trappean intrusions.

Only 3 cases seen.

Granite and quartz veins are also of rare occurrence throughout the southern gneiss area east of the Ghâts, and mostly far too small in size to admit of their being shown on the map, or to be worth enumerating in this memoir. The largest in point of size is one already adverted to (page 16) as occurring on the summit of the Perumal Malai ridge 13 miles north-east of Madura, where it has been irrupted in the axis of a very sharp anticlinal fold. The granite is a pale flesh-coloured binary compound of quartz and orthoclase felspar.

Rarity of granite and quartz veins.

Some fair-sized veins of a ternary granite may be seen cutting across the granite gneiss ridge close south of the Trivadur Trigonometrical Station 5½ miles south-south-east of the Perumal Malai. These veins occupy planes of jointing with a southerly dip crossing the strike of beddings nearly at right angles.

Granite veins in Trivadur ridge.

One group of these veins shows near the end of higher part of the ridge, and when seen from a little distance present a striking resemblance to beds of conglomerate intercalated among sandstones.

South-west of Palamcotta.

About 3 miles south-west of Palamcotta numerous veins of granite are seen permeating the gneiss in a very irregular way. They appear to anastomose throughout the general mass of rock, but are very ill-seen among nearly flat sheet-like outcrops of gneiss; both rocks being moreover very greatly decomposed.

Quartz veins.

The only quartz veins that I noted occur on the western slope of the Serumalai east and south-east of Ammanayakanur Station. They consist of pure white quartz without any included minerals, and are very short and small, only a few yards being exposed in each case. They contain as far as my observation went no accessory minerals of any kind, and have in miner's parlance a decidedly "hungry" look.

CHAPTER IV.

UPPER GONDWANA OR JURASSIC ROCKS.

Before the survey of the Madura and Tinnevelly district was taken up, it was thought very likely that the broad belt of country lying between the area of the gneissic rocks and the fringe of alluvium, which skirts the coast line, might contain representatives of the jurassic and cretaceous rocks which form such interesting features in the geology of the seaboard of the central and northern parts of the Carnatic. Unfortunately no rocks were found which could be regarded as unequivocally representative of either system. Two outcrops of rocks, bearing strong petrological resemblance to some members of the jurassic system forming the Upper Gondwana series of the Geological Survey of India, were certainly found in the Sivaganga country (Madura district), but unfortunately neither outcrop yielded any fossil

remains, by which to identify them with the similar northern beds in Trichinopoly, Madras, and Nellore districts, many of which are rich in remains of plants associated with marine fossils.

These two outcrops of possible Upper Gondwana rocks were met with to the northward of Sivaganga town, the first at Ammersenpatti (a small village not shown in the map) 10 miles to the north-east-by-east and near to Moodechem-putty. The petrological resemblance of the shales found here to some of the hard shales found at Sripermatur (27 miles south-west of Madras) and Vemáveram (14 miles north-east of Ongole, Nellore district) is very great, but no organic remains rewarded a very close search. The shales are not seen *in situ* having been dug out of the bottom of a small tank which was full of water at the time of my visit. A considerable quantity of shale was, however, exposed in clean condition on the tank bund, so that the colour and texture of the rock could be well studied. The prevalent colours were buff and yellow mottled with white. Some quantity was also noted of pink colour ranging to red. A band of white about $\frac{1}{8}$ to $\frac{1}{4}$ inch in thickness, from which the colour had been discharged by some bleaching agency, borders the lines of jointing, which are quite sharply cut. About a mile south-east of Ammersenpatti much debris of a hard shale mixed up with lateritic debris was noticed on the surface of a small opening in the heavy scrub jungle traversed by the cart-road leading south-south-east to Kalayarkovil; there was, however, no shale rock exposed *in situ*, nor could I find any fossils.

Ammersenpatti outcrop.

Very faint traces of similar shales of drab or buffy colour were noticed on the bund of a small *urani*, or drinking-water tank, close to the west side of the road leading from Sivaganga to Tripatur, and about 2 miles north of the former town. The *urani* was too full of water at the time of my visit for any rock to be visible, and I was unable to find any fossils among the small quantity of shale exposed on the bund.

Outcrop north of Sivaganga.

My examination of the last two localities was but cursory, and no opportunity occurred for re-visiting them; future observers will it is

hoped re-examine these localities, and perhaps have the good fortune to find organic remains which will admit of settling the geological horizon to which these shales belong.

Boulder beds.

To the Rajmahal series it will, perhaps, be best to refer certain remarkable boulder beds resting on the surface of the gneiss on the high grounds north-east of Sivaganga and north-west of Seruvayal (Seruvial). These boulder beds appear to be due to the action of surf beating on shoals; for not only do many large and well-rounded pebbles and small boulders strew the surface, but the surfaces of various protuberances of the coarse granular gneiss are worn and rounded *in situ*. These beds are very thin, mere remnants in fact of more extensive formations. They bear a greater likeness to the boulder beds found at the base of the Rájmahál series near Utatur (Trichinopoly District), Sripermatur (Chingleput District), and Ongole (Nellore District) than to any boulder conglomerate in the cretaceous system or in the Cuddalore sandstone and lateritic series. These boulder beds are best seen along the road leading from Natarashenkotai north-north-westward to Kallayar Mangalam. Their extent could not be exactly ascertained owing to the great developement of thick scrub jungle, the absence of all available land marks, and to the badness of the map (sheet 80) which is there utterly wanting in definition. They lie at a considerably higher level than much of the gneissic area to the west of them. No section was met with showing the position of these boulder beds relatively to the overlying lateritic beds.

CHAPTER V.

THE GRITTY SANDSTONES (CUDDALORE SERIES?).

All along the coast of the Carnatic from the valley of the Godavery southward to that of the Cauvery occur at intervals deposits of coarse and generally rather friable sandstones and grits with occasional conglo-

merates which, excepting in one locality near Pondicherry,[1] have proved perfectly devoid of fossils. To these sandstones, which in South Arcot district, where they were first studied, rest unconformably on the cretaceous rocks, the name of Cuddalore sandstones was given by Mr. Henry F. Blanford,[2] who was inclined to think them of tertiary age. Sandstones of identical characters occur largely near Madras and in Nellore districts, while to the south of the typical spread near Cuddalore a large extent of them stretches away from the valley of the Vellár to the northern side of the Cauvery delta. These sandstones have not been mapped separately from the overlying laterite, as they are only exposed over very small areas with generally very ragged boundaries. Moreover, it very often happens that from the base of the lateritic formation being of similar gritty character, it is quite impossible in the absence of any organic remains to draw a boundary line between the two formations. South of the delta similar soft sandstones and grits reappear in the neighbourhood of Tanjore and Vellam, while outcrops of them are met with at intervals in the territory of the Tondiman or Pudukotai Maharaja. The two last or southernmost of these outcrops fall within the limits of the present memoir and map, and therefore require full description. The first of these outcrops occurs on the western slope of the low jungle-covered rising ground 7 miles east of Tirumayam (Tirmium), known locally as the Shenkarai hill. Here an extensive series of rain gullies exposes, but unfortunately only to a very small depth, a considerable surface of gritty conglomerate which dips east-north-east or east-by-north at angles of from 12° to 15°. False bedding prevails but only to a small extent for so coarse a rock. The conglomerate is of mottled brown to pinkish and whitish less frequently reddish-yellow colour and tolerably compact with gritty matrix including quartz and gneiss

Shenkarai section.

[1] At Tiruvakkarai (Trivicary) where silicified stems of large trees, some of them coniferous, are to be seen imbedded. The coniferous wood has been described under the name of *Peuce Schmidiana* by Schmidt and Schleiden in their treatise Ueber die Natur der Kiesel Hoelzer, Jena, 1855.

[2] See Mem. G. S. I., Vol. IV.

shingle (from the size of a cocoanut downwards) in moderate quantity.

Ayangudi section.

The second section of outcrops occurs 2 miles further south-west and about a mile south-west of Ayangudi in the middle of an extensive scrubby jungle. The beds are unlike those east of Shenkarai, as they are rather friable conglomerates of very coarse texture. The matrix, which varies from red to brown-red in colour, is semi-lateritic and vermicularly cellular to some extent. The enclosed shingle is mostly large and well rounded, chiefly quartzose, and all apparently of gneissic origin. The lowest bed is mottled and more gritty in texture with fewer enclosed pebbles. The dip is southerly at low angles, and the section here, as at Shenkarai, penetrates the strata but a few feet vertically. The base of these beds is not seen, but there can be little doubt that it rests upon the gneiss, which crops up at both Shenkarai and Ayangudi.

Ammagudi section.

Eleven miles to the east-by-south of the Ayangudi section, and close to Ammagudi is a section at the edge of the gentle scarp overlooking the Vellár valley in which gritty sandstones are seen peeping out from below the surface laterite. Brown and purple sandstones occur here of sufficient hardness to be worth quarrying into coarse flags for local use. As in both the former cases, the exposure is of very limited extent.

Sections south of the Vellár.

Traces of these gritty beds are to be seen in the tank below the Padi Kasa Nada Kovil (temple) which stands on the bluff overlooking the Vellár river opposite the south end of the Shenkarai hill. Mottled gritty beds are exposed in the Teppa Kulam (square temple tank) at Pallatur (Pullatoor) 4 miles further south. So also 2 miles to the westward of the latter place at Suragudi (Shooragoody) where approximately horizontal beds of mottled grits occur under the laterite. The grits which are exposed in the temple tank only are very clayey in parts and mottled white, pink, and pale buff to yellow. Mottled white and yellowish-brown grits are exposed in rain gullies east

of Shahkotai (Shawcotta) and in the streets on the western side of the town where the ground falls steeply. The whole of this tract of country is thickly covered with massive laterite which masks all the underlying rocks; indeed not a single natural section was seen in which the relations of the laterite to the Cuddalore beds could be studied, while the artificial sections in temple tanks and wells were far too limited in depth and extent to be really satisfactory, even where the presence of water did not prevent the base of the sections being visible.

The most southerly outcrops of grit beds within the limits of the Shahkotai tract was seen at Oodoopooputty 10 miles south-west-by-south of Shahkotai where a white and yellowish-brown mottled grit is exposed underneath the laterite in various small rain gullies. The grits are exposed only to a depth of 4 or 5 feet at the utmost.

No gritty beds were seen in the Seruvayal (Serruvial), nor in the northern and eastern parts of the great Sivaganga tract. In the western part, however, are several outcrops of sandstone and grits referable to the Cuddalore group. The first of these requiring to be noticed occurs about 1½ miles south-east of the town of Sivaganga. Here several beds of hard thick-bedded grit crop out from below the general lateritic covering of the country. In colour the rock is dark purplish-grey with brown bandings, and the dip is about 20° to the north-east. Much diagonal or "false" bedding is seen in the freshly-broken rock, which is overlaid conformably to the eastward by less compact dark-brown and yellow-brown gritty sandstone. The hard grits, which are largely quarried, are so tough as to require blasting. Unfortunately the relation to the lateritic beds cannot be ascertained as the latter are locally absent. About 5 miles to the south-south-west of Sivaganga is a considerable exposure of brown gritty sandstone which forms the upper part of the low scarp overlooking the narrow strip of gneiss rocks which there divides the grits and laterites from the great alluvial flat of the Up-Aru (Hoop-Aur) and Vaigai rivers. It is a sandstone of very peculiar appearance, a

Sivaganga Section.

Section south-south-west of Sivaganga.

curious system of shallow quasi-conchoidal pittings, and the pittings affecting the successive laminæ so as to show on weathered edges a columnar series of pittings super-imposed one above the other with a fair approach to verticality. The pittings often leave shallow interlaminar spaces which are lined with a shining black film of oxide of iron. The dip of the beds is not very clear, but they appear to dip generally to the eastward at very low angles. They are covered up to the eastward by thick, deep red, highly ferruginous soil which is followed still further east by large spreads of massive laterite which covers all the high ground up to the new high road between Sivaganga and Mana Madura. To the south-east of the brown sandstone outcrops the ground continues high, and forms a long-stretched down running south-east for 7 or 8 miles.

Section 5 miles south of Sivagunga.

Where the Sivaganga-Mána-Madura road approaches the crest of this down from the north side, the laterite, which is greatly developed, has the character of a very coarse conglomerate which lies on an equally coarse conglomerate with gritty matrix. Both conglomerates contain many large and small pebbles and some small boulders of granular quartz rock. The grit conglomerate is only exposed in a small well 12 to 14 feet deep near the 5th milestone south of Sivaganga. The lateritic conglomerate which shows a maximum thickness of about 10 feet rests on a much eroded surface of the grits, so that the two formations are certainly unconformable at this place, whatever their relations may be elsewhere. The grit contains many *quasi*-vermicular aggregations of coarse white or mottled clays.

Manambákkam section.

A small show of coarse white or mottled grits occur in the bed of a rain gulley running westward into the Up-Aru, about half a mile northward of Manambākkam (Manambaucum), but the high ground to the east only show here and there very fair sections of the lateritic conglomerate and the grits are not exposed. The southern slope of the long down above referred to is thickly covered with very richly ferruginous hard red loam which is largely overgrown with low scrub jungle.

To the east, and especially to the south-east of Māna-Madura, is a large show of grits of white or yellowish or mottled colours. Though a large surface of the grits is exposed, the sections are very shallow ones, and afford little information about the formation. The beds dip east at very low angles or roll about gently. Near Pikulam (Peculum) the overlying lateritic beds have escaped denudation, and they pass below the alluvium, thus masking the grits which are however seen in one or two places in irrigation channel sections south of Vunneygoody, the most southerly exposures of the Cuddalore rocks in Madura district.

Māna-Madura sections.

The gritty sandstones which occur at intervals along and near to the coast of the Rámnád zemindari are all of unequivocally marine origin, as shown by the numerous marine organisms they include, and no connection is known to exist between them and the sub-lateritic series in this quarter, though there is in many cases very great petrological resemblance between the whitish or greyish varieties of both series. In the far south, however, one section was met with in the right bank of the Yellava Odai, a tributary of the Nambi-Âr in which a very decided connection exists between one of the sub-recent marine beds abounding in fossils and a very typical whitish grit having the strongest possible resemblance to the grit beds at Mána-Madura, and in many sections of the Shahkotai patch. If the petrological similarity between the typical Cuddalore grits and these South Tinnevelly grits be accepted as sufficient evidence to identify them, then the age of the Cuddalore and Rajahmundry beds is established to be not tertiary but recent. This section will be described a little further on.

Section determining the age of the Cuddalore sandstones as sub-recent.

The most northerly occurrences of beds supposed to be of Cuddalore age seen in Tinnevelly district occur in the south-western part of the Tenkarai taluqs to the north-east, east, and south-east of Pettakulam (Vaulacolum of map.) The grits are exposed only in well-sections, the general surface of the country being thickly covered by blown sands or by local alluvia. The grits

Sections in Tinnevelly district at Pettakulam.

exposed in the wells are coarse, mottled reddish-yellow and white, in generally horizontal beds. Not the slightest trace of any organism could be detected.

Nambi-Âr section.

The next outcrop of the gritty sandstones requiring notice is one to be seen 8 miles further to the north-west-by-north, at the junction of the Nambi-Âr or Tirukurungudi river with the nalah rising in the Anaikulam tank. The grit is mottled and much false bedded, and petrologically, as well as in the absence of all traces of fossils, greatly resembles the Nagarkoil beds in Travancore. Only a small exposure of this grit is seen resting on the very uneven surface of the gneiss, but it probably extends a considerable distance under the wide alluvial spread east of the Nambi-Âr. It is overlaid by a highly kankarized, and therefore much altered, pebbly sandstone, of probably alluvial origin.

About a mile to the north-east of this, and about half a mile west of the hamlet called Thopevella in the map, is a considerable show of typical whitish grits very like those seen at Nagarkoil, and described in my paper on the geology of South Travancore (Records G. S. I. Vol. XVI 1883, page 28). These grits are overlaid by a bed of sandy clay full of sub-fossil shells of recent species of Ostrea, Arca, Cytherea, &c.

Yellava Odai section.

The section is small and not very satisfactory, but at one place a band of the clayey sand is distinctly included in the gritty sandstone and appears positively to settle its age. The clayey band encloses many specimens of *Arca granosa* and of a Cytherea (? castanea). Unfortunately, petrological identity excepted, there is no evidence that the gritty sandstone is positively a representative of the Cuddalore series, else the question of the age of the Cuddalore beds might be taken as settled for good and all. As it is, further evidence will be necessary before this point can be regarded as definitely settled. If the Cuddalore grits are really of marine origin, and from their geographical position this seems highly probable, it is certainly strange that they have been found to be unfossiliferous over such extensive areas.

At Pakaneri.

Grits of similar colour, but finer texture, are exposed in a well-section south-east of Pakaneri (Paukanary), and about 1⅛ miles north-west-by-west of the mouth of the Nambi Aru (Naut Aur).

Idindan Karai cliff section.

Some 7 miles to the south-west of the Yellava Odai section occurs another outcrop of typical grits in the low cliff (12′—25′ high) immediately east of the village of Idindan Karai (Iddinge Kurra). These grits, which are mottled, are rather soft, and yield much more readily to the action of the surf than does the overlying hard calcareous shaly sandstone. The consequence is that the base of the cliff gets considerably undermined,—a process which continues till a cliff-fall occurs, and creates a temporary breakwater against the surf. The base of the grits is not exposed, but the bed is probably not more than 12 or 15 feet at the outside, as gneiss beds show through the beach sand at a very small distance to the south-west close to the village. The section is about half a mile long. A small sketch showing a transverse section through the cliff will be found further on (page 58). The grits appear in this section as conformably overlaid by the shaly marine sandstone.

Kudung Kulam outcrop.

Mottled reddish grit is exposed to a small extent in the rain gully traversed by the path just north of the marine limestone plateau lying between Kudung Kulam and the sea. The grit bed is cut into only about 3 feet, so its thickness is problematic. The shaly gritty sandstone seen eastward of Kudung Kulam village is very much altered in its appearance by infiltration of tufaceous lime (kankar) in large quantities.

Perria Manal outcrops.

A gritty calcareous sandstone, of which only a few feet in thickness is exposed, is to be seen on the right bank of the estuary of the Amman Aru (or Panagudi nallah) a little to the north of the village of Perria Manal. The grit, which is unfossiliferous, is badly exposed and greatly weathered.

Various sections reveal the presence of gritty beds under the

alluvium of the Amman Aru, and further west under the great red soil deposit which flanks the spur of the Kathadi Malai stretching south towards Cape Comorin These are of precisely the same character as the grit beds described in my notes on South Travancore (Rec. G. S. I. Vol. XVI, page 29), of which, indeed, they are extensions. In colour these grits are white, pale drab or grey, mottled with red and brown in various shades. Among the best sections of these grits are those to be seen in the bed of the Kothan Aru and its various small tributaries, especially one (not shown in the map) which flows parallel with the old *saleh*, or avenue of trees, leading from Panagudi to Cape Comorin for about half a mile. Another good section is to be seen in a channel cut through the thick red soil to convey water to the Comaraveram tank about ¾ of a mile to the south-east. The beds have a general dip to the southward, but roll about a good deal on a small scale; they show a good deal of local false bedding. The grits are exposed also in numerous garden wells, but all the sections are very shallow, and in no case was the base of the formation seen.

Sections north of Cape Comorin.

Eastward of the Kothan Aru are other gritty sandstones of grey and drab colour, but more friable and shaly and of a decidedly younger aspect. They are exposed in the bed of the Panagudi nalah at and above Perangudi (Perrungoody).

Sandstones of doubtful age.

Of equally doubtful position is a brown gritty sandstone considerably affected by infiltration of kankar, which is exposed to some extent in the shallow bed of the stream which flows out of the large tank north of Nedden Kulam, 4 miles west by north of Shatankulam (Shalaungcolum) in Tenkarai taluq. As the bedding is nearly horizontal, the thickness exposed in the very shallow section amounts only to 2 or 3 feet. This brown sandstone, in which I was unable to detect any fossils, bears little or no resemblance to any member of the grit series which came under my notice in the south, but beyond that there is no reason why it might not be a remnant of the former extension of the Cuddalore for-

Nedden Kulam outcrop.

mation, as might also be a patch of yellowish-brown, coarsely shaly, sandstones exposed in a well-section a little east of Tiruvanguneri, 3 miles north-north-east of Shatan Kulam. Both patches lie in slight hollows which may well account for their having escaped the general denudation which removed so great a part of the Cuddalore group.

No traces of lignite met with in Madura and Tinnevelly.

In none of the outcrops or sections of the Cuddalore rocks or of the unfossiliferous sandstones of the Madura or Tinnevelly district have any traces of lignite been found as yet. In Travancore, however, in the Warkilli beds (which Dr. King believes to be the equivalents of the Cuddalore beds), lignites are a feature of some importance, especially in the lower part of the series. The south-eastward extension of the Warkilli beds at Kolachell also contains small quantities of lignite.

The mottled gritty beds as a rule strongly resemble the typical mottled grits exposed in the low scarps of the Cuddalore sandstone and laterite plateau south-west of Cuddalore town, from which locality their name was originally taken. The whitish grits bear a very strong petrological resemblance to the white grits so well exposed in the low cliffs overhanging the Corteliar river, where it flows round the north-western end of the Red hills plateau to the north-west of Madras.

CHAPTER VI.

THE LATERITIC FORMATIONS.

Similarity to lateritic formations elsewhere.

The rocks which I class under this heading are very similar in general to those assigned to the lateritic group in the more northerly parts of the Carnatic. They consist of ferruginous conglomerates, gravels, and sands, which as a rule follow each other in that succession from west to east. The conglomerates and gravels occupy the higher grounds along the western side of the lateritic area which forms a band of very irregular width lying between

the gneissic area and the coast alluvium, while the sands cover the eastern slopes and extend down to and disappear under the western edge of the overlying alluvium.

Change in mineral character as followed southward.

By far the greater part of the area, which in the map accompanying this memoir is shown as occupied jointly by the Cuddalore and the lateritic series, belongs to the latter.[1] In the northern part of the country under description the most marked feature of the lateritic rocks is their great richness in iron, chiefly in the form of earthy red hæmatite. To the south-westward and southward, however, of the Vaigai river a great change takes place, and the quantity of iron in the gravelly or sandy beds becomes smaller and smaller, and the series is finally represented by a very thin bed of gravel, mostly of gneissic origin, in which the percentage of iron is so small that it has only sufficed to give the quartzose gravel a cinnamon-brown stain.

Sub-division of the great band of lateritic rocks by intervening alluvial valleys.

The great band of lateritic rocks has been cut up by the local alluvial spreads of the rivers into various minor tracts, which may for convenience be designated according to the chief places situated within their limits. Beginning at the north-eastern extremity of the lateritic area we find—

1, the Arrantangy tract lying north of the Vellār river ;
2, the Shenkarai tract between the Vellār and the Pambiār ;
3, the Shah Kotai (Shawcotta) tract between the valley of the Pambiār and the Vershalay Aru (Manimut-Ar or Tripatur river);
4, the Tripatur tract ;
5, the Chattrasingara Kotai tract ;
6, the Serruvayal tract between the Vershalay Ar and the Upp-aru (Hoop Aur) ;

[1] It was found impossible to draw any boundary line between the two formations, owing to the obscurity of the sections in which they were exposed. In a few sections the lateritic beds appear distinctly unconformable to the Cuddalore series, but in others the grits forming the mass of the latter series appears to pass upwards into the former without any visible break.

7, the Sivaganga tract extending from the Upparu down to the Vaigai river;

8, the Mudukan Kulam (Moodoocuncolum) tract which occupies the slightly rising ground between the alluvium south of the Vaigai river and that of the narrow valley of the Gundár;

9, and lastly, the Parnalli tract between the Gundár and the coast alluvium on the north side of the Gulf of Manar.

To the south-westward of the Vaippár (Vypar) in Tinnevelly district only faint traces of the lateritic beds occur, too ill-defined and scattered over the surface of the older rocks to admit of their being mapped. These will be referred to again a little further on.

Arrantangi tract.

With regard to the Arrantangi tract (No. 1), there is nothing more to be said than that it shows the typical conglomeratic form very well along the high-ground on the left (east) bank of the Vellár to within about a mile of Arrantangi fort. Further east it rapidly becomes more and more sandy, and finally so strongly resembles the reddish sandy alluvium seen near the sea, that it is extremely hard to say where the boundary between them should be drawn.

Shenkarai tract.

In the second, or Shenkarai tract (No. 2) the conglomerate is very thick and massive over an area of several square miles in extent and remarkably rich in iron, as is clearly indicated by the rich red colour of the wheel tracks passing over the great bare sheets of rock which are a very characteristic feature of the rock in that immediate neighbourhood. South of Ayangudi a considerable iron smelting industry seems to have existed at some not very remote period, if one may judge by the size and condition of some very large heaps of slags which are there to be seen.

Shah Kotai tract.

By far the greater part of the Shah Kotai tract (No. 3) is occupied by the hard laterite which is often more homogeneous than conglomeratic in texture and covers the surface of the Cuddalore sandstones in extensive and continuous sheets of very dark reddish-brown (almost black) colour. These are specially well seen at Kilanelli Kotai (Keelanelli cottah), where the walls of the

old Poligar fort are entirely built of the massive rock quarried close at hand. They are also very well displayed on the top of the bluff overlooking the Pambiār valley at Neddengudi, and again on the high ground between Shuragudi (Shooragoody) and Kárágudi, and to the westward and south-westward of the latter place ; also in the south-eastern part of the tract to the south and south-east of Amarāvati. The sandy form of the lateritic deposits is much less developed here than in the Arrantangi tract. The sands on the eastern side measuring only from 2 to 3 miles across instead of 7 or 8.

A small inlier of pale reddish sands which rises from out of the alluvium of the Vellár a little south-west of Avadiar Kovil (Avadear Covil), I have with great doubt mapped as of lateritic age. It rises only a few feet above the surrounding alluvium, and is of rather darker colour, but presents no other special feature.

Tripatur tract.

It will be convenient to describe at this place the Tripatur tract (No. 4) which lies to the north and north-west of Tripatur town, the only important place in the vicinity, and forms a narrow strip about 8 miles long and a mile or 1½ mile across at its widest part.

Chattrasingara Kotai tract.

The dense and highly ferruginous form of the lateritic conglomerate is not found largely in this tract, but a less ferruginous and less compact form including large quantities of gravel of gneissic origin. This description will also apply well to the lateritic beds seen in the Chattrasingara Kotai tract (No. 5).

Serruvayal tract.

The Serruvayal patch of lateritics (No. 6) is also a small one lying between the Tripatur river and the Upparu[1] (Hoop Aur). The highly ferruginous conglomeratic form is very largely developed to the north and west of the village

[1] Upparu, or "salt river," is a very common name for small rivers whose water becomes very brackish before they finally dry up. There are three rivers of the name in this part of Madura district : one which forms the headwater of the Tripatur river, that now under reference, and a third smaller one which falls into the Vagai, 8 miles south-south-west of Sivaganga.

of Serruvayal. The sandy variety occurs only at the extreme south-eastern extremity.

The Sivaganga tract.

South of the Serruvayal tract comes the Sivagunga one (No. 7), the largest we have to describe. The spreads of the hard ferruginous conglomerate, though very common everywhere except on the extreme eastern side where a band of from 2 to 3 miles in width of sands prevails, are less extensively continuous and more frequently covered with thick red soil. This appears to be due to some extent to the greater extension of agriculture, in favour of which the surface of the conglomerate has in many places been broken up with picks or crowbars to expose the softer sub-rock which, if not allowed to solidify again by the action of rainwater, weathers into a fairly fertile soil. The most typical developments of the conglomerate near Sivaganga occur to the north-west and north of the town. The environs of Kalayar Kovil (Calliar Covil) also show very typical spreads of conglomerate and of the deep red fertile soil derived from it under favourable circumstances.

Conglomerate at Kalayar Kovil.

At Mangalam.

A very typical spread of hard laterite conglomerate covers a large area on the high ground lying 2 or 3 miles west of Mangalam (Mungalum) and extends north-eastward along the new high road from Shembanur to Sivaganga. The high ground south-west and south of Sivaganga, and its southerly extension past Mana-Madura almost down to the southernmost apex of the Sivagunga tract, is covered with very typical laterite conglomerate, which at intervals shows its true character very markedly by including considerable numbers of rolled pebbles (large and small) of gneissic origin. This may be very well seen a little to the south of the 5th milestone on the new road going direct from Sivaganga to Mana-Madura. The laterite conglomerate here rests unconformably on the eroded surface of an old gritty conglomerate which on stratigraphical and petrological grounds I have referred to the Cuddalore series (see page 39). The laterite conglomerate attains a thickness of fully 10 feet and includes many well-rounded

At the 5th milestone Mana-Madura road.

masses of granular quartz rock, some of them large enough to deserve the appellation of small boulders.

A couple of miles to the south-west the laterite also shows many included pebbles of granular quartz rock lying about on the surface (apparently washed out of the mass).

At near Mana-Madura.

I noticed also sundry angular fragments of a brown chert foreign to that part of the country. Similar angular fragments of an identical chert were noted also in rain-gullies on the top of the scarp of the laterite plateau to the east of Pikulam (Pecolum) 3 miles south-south-east of Mana-Madura. The extreme south end of the Sivaganga tract of laterite rocks is skirted by the Vaigai river, but unfortunately no section has been formed by the river.

Outliers of laterite on the gneiss north of the Vaigai.

There is a very considerable overlapping of the laterite formations on to the gneissic rocks westward of the boundaries of the various tracts now enumerated. Scattered shingle forming the debris of one continuous bed is widely spread over many parts, while patches of the hard ferruginous conglomerate are also to be seen in various places. Considerable remains of such shingle beds are to be seen to the west and north-west of Melur, *e.g.*, at Mankulam (Maunccolum) 6 miles to the west, and again a little to the south and south-east of the great Allagiri temple at foot of the Allagiri hill. The shingle here, which is very coarse, is stained of a deep red, proving that it was once embedded in a highly ferruginous matrix. It is scattered over an area of several square miles in extent. Many patches of ferruginous conglomerates are scattered over the gneissic plains to the north-west and west of the Sivaganga laterite tract.

Lateritic shingle west of Melur.

North of Madura.

To the north of Madura town considerable remains of a very typical highly ferruginous laterite conglomerate rest on the surface of the gneiss north of the Tallakulam (Tullacoolum) tank at a level high above that of the alluvium of the Vaigai river. A great quantity of shingle of gneissic origin is mixed with the ferruginous gravel, and in some places compacted by a ferruginous cement

into typical conglomerate. Associated with the shingle are occasional flakes of brown, buff, or greyish chert of foreign origin, some of which certainly seem to have been trimmed for use as scrapers or knives.

Mudukan Kulam tract.

Coming south of the Vaigai we reach the Mudukan Kulam (Moodoocumcolum) tract (No. 8) which I have named after the village giving its name to the only trigonometrical station shown on the map (sheet 80) in that region, as no more important place lies within the limits of the patch in its typical and unmistakable portion. The tract is a long and narrow one lying between the alluvial valley of the Vaigai and that of the Gundâı and extending a distance of about 36 miles from north-west to south-east with an average breadth of 8 or 9 miles.

Prevalence of gravels and sands.

Thoughout by far the greater part of this tract the lateritic beds show a gravelly or sandy and but slightly ferruginous character. The hard conglomeratic variety occurs only in small patches here and there, all in the northern half of the tract. None of these patches are worth separate mention, but they are indicated in the map by letters. The sandy parts consist generally of pale reddish or reddish-white sands with a variable quantity of ferruginous pellets of concretionary origin. Included gravel or even coarse shingle is frequently met with in the northern part, not so much in distinct beds as distributed through the general mass of sand.

Former western extension of gravelly beds.

These gravelly beds had formerly a very much greater extension westward, and considerable remnants of them remain scattered over the gneissic rocks, but in patches too ragged and too much interrupted by protruding masses of the gneiss to admit of their being separately mapped on the small scaled map (4 inches to the mile), which alone is at present available for the Madura country. Several such patches of gravel are noteworthy on either side of the Gundar valley close up to Tirumangalam and at intervals for some 3 or 4 miles northward of that place.

Nature of the gravels.

By far the greater quantity of this gravel consists of rolled granular quartz rock derived from some of the many outcrops of that very peculiar member of the gneissic

series to which so much attention has been drawn in foregoing pages. Other gneissic rocks have also furnished a few pebbles, and a few stray ones of chert and one or two of agate were noted as well.

Concretionary and accretionary ferruginous pellets.

Besides the concretionary pellets of earthy hæmatite with a smooth and often glazed surface which are of common occurrence wherever the sands or gravels are richly ferruginous, there is another form of pellet of very frequent occurrence even in the less richly ferruginous beds. This differs from the other in consisting of a mere aggregation of grains of sand by a ferruginous cement which shows no concentric arrangement. This form of pellet is almost always rough on the surface from the projection of numerous grains of sand, and the gravel it forms is invariably due to deposition of ferruginous matter by water at various levels. Where this action has been long enough continued the pellets are aggregated into a quasi-conglomeratic mass, the real origin of which is sometimes not very easily discernible.

Pale gravels at Abiramam.

As might be expected, the gravels in the more easterly part of this tract are much less coarse than those occurring at higher levels and further inland. In the extreme south-easterly part near Abiramam (Abramum) the gravels are but very slightly iron stained, and the pebbles of rolled granular quartz rock, which form fully 95 per cent. of the whole, are of a pale cinnamon colour tending to pale ochrey yellow.

The Parnalli tract.

The last and most southerly tract which I have called the Parnalli tract (No. 9) shows like the foregoing one a much smaller development of the ferruginous forms of lateritic rock than do the tracts north of the Vaigai river. This tract differs from all the others in that its surface is to a very great extent masked by a thick and, in the southern part especially, almost unbroken sheet of regur or cotton soil. Owing to this extremely thick covering and the great paucity of sections, the area of the tract as shown on the map must be received as only a very rude approximation to the truth.

Great spread of regur.

In the northern part of the tract the pall of cotton soil is wanting, and

there the reddish sands of ordinary type prevail with one or two small patches of hard dark coloured highly ferruginous laterite conglomerate.

Outlying gravel beds at Mantapa Salè.

A considerable area of the gneissic country north-west of the Parnalli tract is covered with a broken and discontinuous sheet of gravel and shingle of lateritic age, which covers a small plateau extending from the great tank at Parallache, north-westward to a little beyond the American Mission station at Mantapa Salè (Mundagashaulay). Here and there the gravels are cemented by a ferruginous conglomerate into a true coarse conglomerate, but in general they are non-compacted. The mass of the gravel consists of granular quartz rock well rolled, but with a fair sprinkling of other pebbles of gneissic origin. A considerable number of rude flakes and some good-sized angular lumps of a brown or greenish brown chert with almost very smooth surfaces were also noted.

Pale gravels at Parnalli.

In the southern part of the Parnalli tract only a few tank and well sections show a pale granular quartz gravel. The most important of these exposures, and really very trifling ones, *per se*, occur at and a little to the west of Parnalli village, and a slight terrace rise of the ground which sweeps round both north-east and south-west of the village appears to show the emergence of this gravel from below the great alluvial spread to the south.

Pale gravels near Velati Kulam.

Occasional traces of similar pale yellow or cinnamon coloured gravels show at intervals over the gneissic tract westward of the Parnalli lateritic tract, but there also the face of the country is greatly masked by thick cotton soil, and the gravels are exposed only in artificial sections as wells, tank bottoms and the ballast pits along the high road to the north of Velati Kulam (Vullauticolum). The gravels are often largely mixed with gravelly kankar (small nodular tufa).

South of the Vaippar (Vypar) there is a long stretch of country over which no sections exhibiting gravels were met with, though they very likely occur in detached patches under the surface of the wide spreading sheets of cotton soil which cover so large an area in Eastern Tinnevelly.

The first show of gravels noted south of the Vaippar occurs at Timmarajapuram, south-south-west of Meltattapparai station on the

South Indian Railway. A good deal of shingle shows also on the low granular quartz ridges east of Timmarajapuram and thence southward at intervals for a mile or a mile and a half south of Vagai Kulam along the road from the railway down to the delta of the Tambraparni. Here and there these gravels are much mixed with impure red hæmatitic gravels, and then get solidified to a great extent. They are everywhere very thinly scattered over the gneiss with too many outcrops of the latter protruding through them to allow of their being separately mapped on a small scale.

Patches of shingle at Timmarajapuram.

South of Vagai Kulam.

A few extremely small traces of these gravels were met along the eastern foot of the Vallanād hill, while a few of the masses of granular quartz forming the rather extensive talus on the same side of the hill show distinct traces of rounding and polishing by water action. There can be no doubt that during the period of depression when the various gravel beds now enumerated were being deposited, Vallanād hill and many of the other hills rising out of the plains of Madura and Tinnevelly districts must have been islands either in the sea or in some very widespread fresh-water lake or lagoon, and that the talus of debris surrounding the various islands must have been exposed to considerable wear by local surf action. Such surf-rolled taluses are well known further north in the northern half of the Carnatic, *e.g.*, the great shingle banks along the south flank of the Nagari mountain in North Arcot district, and similar banks along the eastern base of the Vellakonda mountains, or Eastern Ghats in Nellore district. The hard and durable nature of the dense varieties of the quartzite has caused the shingle formed from it to maintain its true character despite long continued weather action. The brittle character on the contrary of the granular quartz rock will readily account for the degradation of the coarse shingle talus which must have been formed round the islands standing up out of the lateritic sea or lake. Traces of such shingle were noticed also near the base of the Sangani hill (Trigonometrical Station), south of Tinnevelly and on the Pasu Malai south-west of Madura.

Gravel talus of Vallanād hill.

To the south of the Tambraparni river hardly any traces of the pale non-ferruginous gravels remain. One very faint sprinkling of such gravel was noticed about half a mile east of the village of Mananjapatti (Keel Monunjaputty), 14 miles south-by-east of Palamcotta. Very little also of the ferruginous conglomerate is seen south of the Tambraparni except in the southern half of the Nanganeri taluq, where numerous patches are to be found scattered over the surface of the gneissic rocks, *e.g.*, along the high road from Valliur (Vullioor) to Radapuram (Rauthapoorum) and the salt-pans (now abandoned) on the Vijayapatti (Vissiavethee) creek. Much similar ferruginous conglomerate is to be seen along a parallel line of country about 3 or 4 miles to the westward. Some of these patches of laterite may be of sub-aerial origin, but it is very difficult and often impossible to distinguish them from the sedimentary rock during a cursory examination, and the formation is certainly not one of sufficient importance, either geologically or economically, to justify the expenditure of much time in settling the question in the case of small and obscure patches.

Gravels at Mananjapatti.

Lateritic conglomerate near Radapuram.

None of the lateritic deposits met with in Madura or Tinnevelly threw any light on the debateable question of the marine or fresh-water origin of the sedimentary laterite, as none of the tracts surveyed yielded even the faintest trace of any organism. To my mind the marine hypothesis still seems to present the smaller number of difficulties, but I will not attempt to enter upon any further discussion of the question here.

Marine or fresh water origin of the laterite still unsettled.

In conclusion it may be well to draw attention to the general resemblance of the non-ferruginous shingle and gravel beds of the south to those occurring in the neighbourhood of Madras and described by me under the name of Conjeveram gravels in the memoir on the geology of Madras published in Volume X of the Memoirs of the Geological Survey of India,—see also Manual. The most marked resemblance to this Conjeveram gravel is presented by the shingle exposed at the western end of

Resemblance between pale gravels and Conjeveram gravels.

the small laterite tract of Tripatur (see page 47), in the non-ferruginous parts of which the pebbles are greatly bleached and much mixed with a whitish clayey grit. Allowance has, of course, to be made in contrasting these formations for the different character of the rock forming them. In the case of the Conjeveram beds the gravel consists most largely of hard quartzite derived directly, or indirectly, from the vast quartzite beds of the Kadapa series, while the southern shingle beds are made up of rolled pieces of the granular quartz rock which plays so important a part in the metamorphic country south of Trichinopoly.

CHAPTER VII.

THE SUB-RECENT MARINE BEDS.

A very interesting series of marine rocks, generally more or less calcareous grits, forms a narrow and rather broken fringe along the coast from Cape Comorin to the Pamban (Paumben) channel. These beds can in great part be regarded only as the ruins of a once far more widely extended formation, by far the greater portion of which has been removed by denudation. Here and there outliers and patches of these beds have been left, which testify to the fact that since their formation under the sea the country must have undergone an elevation of close upon 200 feet, if not more; others of the marine beds, however, have been upraised to a very much smaller extent, or were, what seems even more probable, deposited at a later period while the elevatory action was still in progress. Despite this very great difference in the level of the several marine formations belonging to this group, it was found impossible to assign them to more than one group, and as far as my examination of these two stages of marine formations and their organic contents went, I was unable to perceive any biological grounds for their separation, for both contain only species such as are now found living in the adjoining sea.

In describing the several patches of this marine group, it will be

simplest to take them in geographical sequence from south-west to north-east, the order in which I worked them out myself. Three exposures of similar beds which occur in the Travancore territory along the coast between Cape Comorin and the Tinnevelly frontier will be found described in my paper on the Geology of South Travancore (Records, G. S. I. Vol. XVI, 1883, page 30). The two first patches of recent marine rock met with along the Tinnevelly coast are to be seen on either side of the strip of land between the estuaries of the Kothan-Ār and Hanamanadi. The calcareous gritty beds here seen are raised but a very few feet (2′—5′). above the present sea level, and are ill seen, while the paucity of organic remains included in them makes them of very small interest. It is possible that the strips of red and white blown sand which skirts the coast for 4 miles westward, between the mouth of the Kothan-Ār and the richly fossiliferous patch of limestone at Kannakapur may conceal the eastward extension of the latter beds, if not other marine beds as well. The small patch of calcareous grit lying east of the Amman-Ār has its eastern side covered up by the end of a small teri, or blown red sand-hill, which extends eastward for about 3 miles parallel with the coast line.

Peria Manal outcrops.

To the north of this red sand-hill rises a small limestone plateau about 2 miles long from west to east, and about three quarters of a mile wide at its greatest width. On the highest part of this plateau stands a small masonry building, which was the southern observing station of the Trigonometrical Surveyors when engaged upon the Cape Comorin base line. The elevation of this station is given by them as 159 feet above sea level. A small and narrow valley cuts off this plateau to the eastward from another limestone plateau of about the same elevation at its western end, but sinking very gradually to within a couple of hundred yards to its eastern end, when it slopes rapidly down to the mouth of the Viziapatti (Vissiavethee) creek. This plateau becomes so narrow at its eastern end above Idindan Karai (Iddinge Kurra) that it might perhaps be preferentially called a ridge. It is

Kudung Kulam western plateau.

Kudung Kulam eastern plateau.

here also much obscured by considerable accumulations of teri sand and along the coast, by the ordinary dunes.

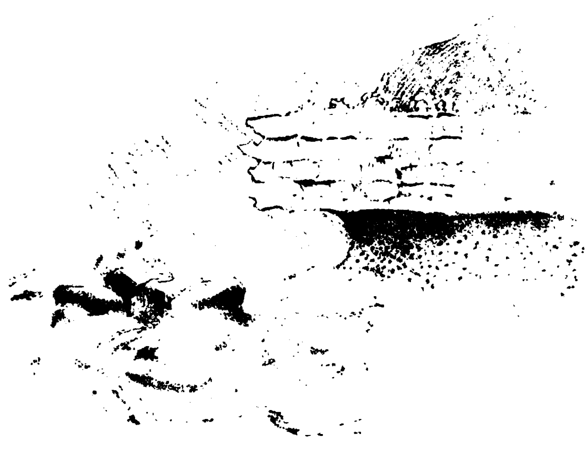
The limestone varies from a typical variety weathering to an almost chalky surface to a slightly calcareous grit. The prevalent colours are greyish-white and drab to light brown. The more gritty variety of the limestone occurs at the south-western extremity of the eastern plateau, where it forms a capping bed fully 4 feet thick. The most gritty parts of the bed contain a large percentage of coarse quartz grit and sand. The dip of this bed and of the beds in many parts of the western plateau is northerly at very low angles, or else the beds are horizontal. Fossils are not very easy to distinguish in the limestone, nor are they numerous in an entire condition, although large quantities of comminuted marine shells are common in some beds. I failed in finding a section showing the relation of the limestone to the gneiss, but in one section along the path leading direct south from Kudung Kulam there is a small exposure of pale mottled grit which underlies the limestone. Whether this grit, which is unfossiliferous locally, re-appears below the limestone along the south side of the plateau, I was unable to ascertain, owing to the amount of talus resting on the scarp overlooking the strip of gneiss which here forms the coast. I estimated the thickness of the limestone from 50 feet to 60 feet or more. Near the observatory and in the village of Kudung Kulam I noticed some fine blocks of a dense cream-coloured limestone of considerable beauty, but could not find out, despite many enquiries, where this variety had been quarried. A rather different and more shelly (comminuted shells) cream-coloured limestone was crossed in following a path leading from Kudung Kulam to the west of Idindan Karai (Iddinge Kurra).

The fossils collected were some few oysters and a number of large and long Balani. These were found at the extreme western end of the eastern plateau. The specimens collected at the north-eastern corner of the western plateau about half way up the limestone slope, were as follows :—

Purpura persica.
Mazza rapa ?
Lithodomus, sp.

There can be no reasonable doubt of the northward extension in former times which has been referred to above, but I had not the good fortune of finding any remains of the limestone on the north side of Kudung Kulam valley; but as the whole of the north side of the valley is thickly covered with red soil, it is quite possible that remains of the plateau may yet lie hidden there. As already stated above, the limestone of the Kudung Kulam eastern plateau slopes gradually but considerably to the east, but is unfortunately very much masked by the blown sand of a small teri and by a considerable formation of impure tufa underlying the teri formed by evaporation of calciferous rain-water filtering down from the highest part of the ridge. Like the recent tufa (travertine) described as occurring at Cape Comorin (see Records, Vol. XVI, p. 30), this formation contains very large numbers of the living Helix vittata in a fossil condition. This travertine extends down to the slope of the ridge, and to the very edge of the low cliff which extends for about one-third of a mile east-ward from Idindan Karai (Iddinge Kurra) village. Underlying this travertine is a bed of hard calcareous sandstone of whitish

Idindan Karai cliff section.



Idindan Karai cliff (diagrammatic).

or drab colour, and containing large numbers of marine shells of living species. Of the shells some appear perfectly fossilized, others are but very slightly altered and retain part of the natural colouring. The latter lie within reach of the constant action of the surf spray; the former lie above it, and are exposed to the bleaching action of the sun. This calcareous sandstone attains a maximum thickness in the eastern and central parts of the cliff section of about 10 to 12 feet, but thins out to the westward till close to the village where it is covered by blown-up beach sand. Its connection with the gritty limestone of the eastern end of the Kudung Kulam east plateau could not be traced, being obscured by the teri sand and surface travertine above spoken of, besides which the surface is much hidden by thorny scrub. If this low level calcareous sandstone is an extension of the higher lying gritty limestone, there must be a considerable southerly roll of the bedding to the north of the cliff section, for in the latter the bedding is horizontal. The relation of the two formations must for the present remain undecided. One point, however, in favour of their being of the same age and horizon consists in the remarkable similarity of the rather soft mottled grit underlying the calcareous sandstone at Idindan Karai to the mottled grit exposed below the Kudung Kulam limestone plateau on the path leading from the village to the beach (see page 42). In both sections the mottled grit appears to be conformable to the overlying calcareous formation. The base of the grits is not seen at Idindan Karai, being hidden by the beach sand and being close to the edge of the surf, which during high tides, or in rough weather, breaks against the foot of the cliff and undermines it very considerably owing to the great hardness and tenacity of the calcareous sandstone, which projects for several yards beyond the soft grit bed. Occasional falls of the sandstone take place, and the fallen masses form for a time a very effectual breakwater against the further encroachments of the surf. The cliff showed smaller traces of the destructive action of the surf than might have been expected from the very exposed situation which it occupies on the coast. This is no doubt due to the protective action of a reef

which runs along the coast at a small distance from the shore. A small ridge of gneiss also runs out into the sea immediately south of the villages and checks very greatly the force of the heavy rollers which break on this coast during the south-west monsoon.

The shells and corals obtained from the calcareous sandstone are the following:—

Turritella.	Arca, sp.
Trochus.	Ostrea, sp.
Nerita albicilla.	Balanus, sp.
Ancillaria albifasciata ? .	Astrea, sp.
Euchelus carinatus.	Porites, sp.

Most of these were got from the upper part of the beds along the ridge of the cliff. The fossils seen plentifully in the lower part were out of reach of hammer and chisel unless a ladder had been available. Many were also exposed along the lower surface of the bed where undermined by the surface, but to extract them by hammering, unless the projecting mass had been carefully shored up with strong timbers, would be very dangerous, and pretty though they are they are not worth risking one's life for, even if time allowed of one's trying to obtain them.

Viziapatti limestone.

Immediately north and east of the mouth of the Viziapatti creek, and only about a quarter mile east of the eastern extremity of the Kudung Kulam eastern plateau is a patch of dark, impure, marine limestone abounding in shells of living species. The limestone lies on a flat and is greatly hidden by a dense thicket of Acacia planifrons and other thorns, and by the village which stands on it. This limestone seems to rest directly upon the gneiss, reefs of which appear close by in the bed and at the bar of the creek. I was unfortunately unable to spare the time to re-visit this patch and make a collection of the enclosed shells. From its position this limestone may very likely be an extension of the gritty limestone at the easternmost end of the Kudung Kulam plateau.

Nambi-Ár section.

The next show of marine beds is at the mouth of the Nambi-Ár 4 miles to the north-east of Viziapatti. The beds consist of calcareous grits and sandstones of

various degree of coarseness, the finer beds being generally the richest in fossils, which are all of living species. Except when exposed by weather action, the fossils are difficult to extract in recognisable condition owing to the hardness of the matrix. The gritty beds show a good deal of false bedding locally, and the beds exposed on the eastern side of the estuary have in one place a strong easterly dip as if they had been uptilted, but this only extends for a short distance and may have been due to the action of a strong local current prevailing at the time of deposition. Only a narrow strip of the marine beds is exposed on either side of the river and southward for about half a mile along the coast. A teri hides the western extension of the beds on the western side of the estuary, and the western ends of the coast dune and a parallel teri do the same for the shelly beds east of the estuary. I was first introduced to this interesting patch of marine beds by the Right Reverend Bishop (then Dr.) Caldwell in 1869, when I devoted several hours to collecting the fossil shells, which had all to be chiselled out of the hard rock. On the occasion of my second visit in 1882, I found that the teri and dune sands had covered up much of the sandstone surface before exposed. The fossils obtained from the Nambi-Âr beds were as follows:—

Cypræa Arabica.	Cerithium, sp.
" sp.	Ostrea, sp.
Conus punctatus ?	Arca granosa.
Purpura persica.	Cardium, sp.
Turbo, sp.	Cytherea, sp.
Trochus, sp.	

Yellava Odai section.

In the section near the bank of the Yellava Odai (an affluent of the Nambi-Âr), described at page 41, is a bed of calcareous clayey sand abounding in marine and estuarine shells of living species resting upon, and in one place distinctly intercalated between white gritty sandstones of typical Cuddalore aspect. The grit is nowhere seen to be fossiliferous. The patch of marine beds is but ill-exposed owing to a thick covering of sandy soil. It is only in the south bank of the Yellava Odai and in the banks of a rain-gully opening into it that the beds are exposed continuously for a few

hundred yards. The depth of the section is also very trifling, and nowhere exceeds 4 or 5 feet vertically. The calcareous sandy clay, which is of yellowish or brownish ochrey character, is richly charged with large and small oysters; Arcas, closely allied to, if not identical with, *A. granosa* and Cythereas, possibly referable to *C. castanea.* The oyster bed may be traced for fully a mile to the north-west as a thin fringe lying in spreads and patches on the surface the gritty sandstone which itself rests on the gneiss.

Puliman Kulam outcrop.

About 1¼ mile east-by-south of the junction of the Yellava Odai and the Nambi-Ár, and about the same distance south-south-west from Puliman-Kulam pariah village, is a tiny outcrop of grey limestone showing in the middle of the teri. I did not observe any fossils in the limestone, but close by I picked up two large subfossil oysters of the same species as that occurring in the Yellava Odai oyster bed.

Tissianvilai section.

The next occurrence of the marine beds following them in a north-easterly direction is at Tissianvilai (Teggayamvella) in a well-section in a garden on the west side of the high road as you enter the village from the south. The well is revetted, but at the time of my visit a small heap of the excavated rock lay close by and showed a purple-brown, coarse, but rather friable, grit with many marine shells. The only entire ones which I was able to extract were valves of the little *Venus scabra,* of a small Arca and a specimen of *Dentalium octogonum,* all of them shells very common at the present day in the Gulf of Manaar.

Bishop Caldwell's quarry.

To the north of Tissianvilai, as the ground begins to rise on approaching the south end of the great Sathan Kulam teri, is a patch of hard calcareous rock, varying from a nearly pure shelly limestone to a very coarse grit, cemented by a calcareous cement and almost quite devoid of fossils. The limestone would be almost entirely hidden by the teri sand, but for numerous pits which have been dug to allow of the quarrying of the rock which is carried on on a rather large scale, there being a considerable

demand for troughs, pillars, &c., &c., cut out of the more purely calcareous parts. The beds show strong signs of having been accumulated in the presence of considerable currents, there being much false bedding in the gritty parts of the rock and also considerable drifting together of comminuted shells. Most of the shell fragments are too small to be recognised with any certainty. The most conspicuous fossil is a large and long Balanus, which must have been extremely common as its fragments make up a large part of the shelly masses. It appears to be identical with that occurring so commonly at Kudung Kulam. The bedding is nearly horizontal where normal. The dip, if any exists, is at an extremely low angle south or southward. The general colour of the limestone is creamy, darkening to a warm pale brown. Besides the Balanus just mentioned, entire specimens of which show numerously here and there, only a few oysters and a single specimen of a pectinoid shell were observed, but owing to the great toughness of the rock it is almost impossible to extract any of the fossils in entire condition. It was from this quarry that Bishop Caldwell got the stone of which he built the noble gothic church at Idayangudi.

Mottled yellowish-white sandstones show in well-sections some little distance to the northward, along the path leading to Suviseshapuram Mission Station.

Outcrop in Satan Kulam teri.

In the map accompanying his paper on the geology of south-east Tinnevelly, Bishop (then Dr.) Caldwell shows a small patch of the marine beds as exposed near the centre of the great Satan Kulam teri. I have no doubt as to the perfect correctness of this observation, but was unable to find the patch in question which has most probably been covered up by the advance eastward of the sands which is considerable in the high parts of the teri. It is very probable that some future observer will find this patch of the marine beds re-exposed by the onward march of the blown sands.

Outcrop north of Taruvai lake.

Two or three miles east of the teri and about a mile north of the Taruvai lake I came across an exposure of estuarine beds full of subfossil shells laid bare by the

trenches of limeburners in search of the shells which are largely used for lime making.[1] The bed laid open by the diggings is an impure shell marl abounding in well preserved shells of Cytherea and Potamides.

The surrounding country for miles consists, except where the small lakes already referred to occupy small hollows, of thick red sands which may in great part be considered as unheaped up teri sands. Unfortunately these sands so completely mask the face of the country that it is quite impossible to correlate in any satisfactory way the marine or estuarine beds exposed in only the far distant outcrops and exposures now under description.

Outcrop at Elanjuné.

A couple of miles to the south-south-east at Elanjuné, a small fishing hamlet on the coast, which was used by the missionaries of the S. P. G. and C. M. Societies as a sea-bathing sanatarium in the days before railways had reached Tinnevelly, is an outcrop of gritty sandstone underlying the coast dunes and extending eastward into the sea in the shape of a small spit (not shown on the map) which appears to join the reef running with a few short breaks parallel with the coast all the way to Manapadu headland. No fossils were seen in the sandstone exposed at foot of the cliff. The reef has the effect of keeping off sharks to a great extent, so that sea-bathing was practised here by Europeans for many years without any accidents occurring. This is also one of the few places on the Indian coast resorted to by dugongs; they have often been seen by the visitors, but the animals are exceedingly shy and wary and will not allow any one to approach them.

Christianagaram sections.

The next exposure of the marine beds, taking them as they follow in a north-easterly direction, occurs at Christianagaram about 4 miles north-west-by-north of Manappadu headland. Here a well sunk a few dozen yards east of the S. P. G. Mission house cuts a white shelly limestone several feet thick

[1] Owing to the great faultiness of both the Atlas sheet and the Revenue Survey Maps in the matter of names, I found it impossible to identify any of the hamlets and villages on the northern side of the lake.

and made up almost entirely of separated valves of *Venus scabra* drifted together. A little to the east of the village is an exposure of shelly marl containing innumerable valves of a Cytherea and many shells of *Helix vittata* and *Nanina tranquebarica.* From its position this shelly marl may be inferred to rest upon the Venus bed.

Manapadu and Trichendur sandstones subaerial.

An estuarine deposit seems in course of formation in the bed of the back-water running along the coast from Kulasekhara-pattanam to Trichendur. Great masses of sandstone occur at Manapadu and at Trichendur, but they seem to be mainly subaerial in their origin and will therefore be considered further on when treating of the coast dunes. The base of the cliffs in both cases are surrounded by a narrow fringe of reef which presents the appearance of fringing coral reef, but I could not see any live coral growing in either.

Panamparai quarry sections.

To return to the unquestionably marine beds. The next outcrops to be recorded occur 7 miles to the west-north-west of Christianagaram or Kalan-Kudi Iruppu (Kaulungcoode-irripoo), at a place called Panamparai (Pannumpaura). The beds here seen strongly resemble those already described as occurring at Bishop Caldwell's quarry at Thisianvilai (Teggayamvella) and are like them a shelly calcareous grit. Being greatly in demand as a building stone they have been largely quarried, but the quarries have not been worked deep enough to expose the underlying rock. They have furnished the material for the construction of the very fine church at the Church Mission Station of Megnanapuram, 3 miles to the east. The beds lie horizontally or dip at a very small angle to the south-east. False bedding on a small scale is common, and the accumulations of fossil shells present the appearance of having been found by drifting currents. As at Tissianvilai, the fossils are very difficult to extract in a whole condition. All that were determinable belonged to living species, but many were far too much comminuted to allow of even generic determination. The Balanus which is the most characteristic fossil at Tissianvilai is common also at Panamparai. The prevalent

colour of the calcareous grit is a brownish cream colour, ranging to decided brown in some cases, and to whitish drab in others. That these beds extend north-north-eastward under the sands of the great Megnanapuram teri is proved by shelly calcareous grits having been cut through in sinking a well through the sand about half way between Megnanapuram and Nazareth. An outcrop of brown calcareous grit occurs at a considerable elevation above the general level of the country about 2½ miles south of Nazareth and in the high part of the teri close to the track leading from Nazareth to Kayampulli (Koyambully). As the masses of rock here exposed are low and lie in the furrow between two high waves of the loose red sand, it is very likely that they may be covered up and lost sight of at some future time. This is the last exposure of the recent marine beds seen south of the Tambraparni river.

Outcrop in the Teri near Nazareth.

To the north of the Tambraparni only two patches of this marine formation were met with in Tinnevelly territory; of these the first was one of considerable extent and importance; the second far too small to be shown on the map.

The first lies along the edge of the high ground which slopes up westward from the coastal band of alluvium to the southward of the Malattar odai (nullah). The rock is here also a calcareous gritty sandstone resting apparently on the gneiss, the junction with which however was not seen owing to the thick stratum of cotton soil which here covers the whole country. The most southerly indications of this bed of grit are found in well-sections lying some distance south-west of the little village of Dalavaipuram (Thullavapoorum) 9 miles north-by-west of Tutikorin. From the shape of the ground, however, there is every reason to believe that the grit extends a mile or more to the south-westward under the cotton soil. It stops short, however, of reaching the Tutikorin-Ettiapuram high road. To the north-east the grit extends up to the village of Vedanattam (Vaidanuthum) and then dies down under the alluvium of the Malattar odai. The best sections of this bed are to be seen in

Vedanattam calcareous grit beds.

the large pits a little south-east of Vedanattam in which the stone is extensively quarried. A few small pits along the road running southward from the village and a few flat outcrops (bed surfaces) where the cotton soil has been denuded away are the only other sections by which to study this grit. As seen in the great quarry at Vedanattam, the beds which roll about slightly consist of fine or coarse gritty calcareous sandstone of pale whitish or pinkish-brown colour and showing here and there "false bedding." Marine shells and Balani are not uncommon and are well preserved, but difficult to extract unbroken. Many of the shells were broken before being imbedded. Much of the stone, which is very well adapted for building purposes, is carried to Tutikorin.

Melamandai section.

The second occurrence of a rock referable to the recent marine series to the northward of the Tambraparni river was noted a few hundred yards south-west of Velayudapuram, a small hamlet 1¼ miles south-west of Melamandai (Mailmuntha). Here a few square feet of brown gritty calcareous sandstone are badly exposed in a small roadside pit. No traces of fossils were seen in this case.

Sections in Madura district.

Continuing to follow the marine beds in a north-easterly direction, the succession in which they were really worked out, we now pass out of Tinnevelly into the Rāmnād zemindari which form the south-eastern portion of the Madura district. The first outcrop of the marine beds met with in the Rāmnād territory is immediately south of the ford over the Gund-Ār (Coond Aur) and on the right bank of the river. Here a low cliff has been formed by the river cutting into a bed of rather soft gritty sandstone abounding in fossil shells, all of living species. The sandstone is exposed for about 300 yards to a depth of from 10 to 12 feet. The base of the section is hidden by the water or very recent alluvium. The following list of fossil shells includes all that I was able to collect :—

Gund-Ār ford section.

Terebralia telescopium.	Arca, 3 sp.
Pyrazus palustris.	Cardita antiquata.
Cuma sacellum.	Venus scabra.
Eburna, sp.	" squamosa.

Oliva, 2 sp.	Nucula.
Sigaretus, sp.	Donax.
Terebra, sp.	Cytherea.
Ostrea, sp.	Corbula.
Plicatula, sp.	Tellina spengleri.
Pecten, sp.	" sp.
Cardium, sp.	" sp.
Pectunculus, sp.	Meroe picta?
" tenuistriatus.	" sp.

Gondâr estuary section.

A broken outcrop of the gritty beds may be traced for some distance below the ford cliff section, but a gap of about half a mile or more intervenes before reaching the estuary of the river, which reveals two bands of hard, more or less shelly sandstone forming very low causeway-like ridges, which stretch nearly across the backwater formed by the bar at the mouth of the river. The strike of the beds is east-by-south to west-by-north, and the dip varies from 5° to 10° south-by-west. The beds have been cut through in several places by the erosive action of the river when in flood, and several small islands have thus been formed. All the fossil shells seen belonged to living species. The path leading to Mukkurpatanam (Mookoorputnumchary) crosses these beds.

Valimukkam cliffs.

The next show of rocks containing living species of marine shells occurs at Valimukkam (Vaulimookum), some 9 miles to the eastward of Mukkurpatanam, in the form of a low rocky spit jutting out into the sea for fully two-thirds of a mile. I refer these rocks with some hesitation to the present group, as I am not quite sure whether they may not owe their origin to sub-aerial action rather than to deposition on the bed of the sea. In parts certainly they bear a strong resemblance to a consolidated coast dune. The distinction is one not always easy to make, and the cursory examination I had to be content with did not suffice to settle the question to my satisfaction. On the northern side of the spit, the beds show a coarse shelly friable sandstone of brown colour, mostly horizontally bedded, and showing but little false bedding. The included shells are mostly comminuted. The beds are exposed in a low cliff facing north, but are completely covered up by blown sands to the

southward, which is unfortunate, as it prevents one's tracing their connection with another series of sandstones which occur on the south side of the spit. These latter beds which show a southerly dip of from 10° to 15° or more, consist of hard massive sandstones of varying colour and composition.

In parts these sandstones are nearly purely silicious, in others they are highly calcareous, because including a large percentage of comminuted sea shells. In some places the sandstone contains no shelly fragments, but consists solely of laminæ of quartz and magnetic iron sand, mixed or distinct, as the case may be. A general admixture of garnet sand, sufficient in quantity to give the whole rock a ruddy colour, is common, but the garnet sand does not often form distinct laminæ by itself. Some beds are found in which a four-fold mixture prevails. The sandstones are best seen close to the surf by which they are occasionally undermined. They have also been very largely quarried at some former time. At the extremity of the spit an identical sandstone contains many shallow little basins, in a good number of which a growth of coral is now taking place. The question to be solved with regard to these sandstones is whether they represent a true sub-aqueous deposit which has been upheaved to an elevation of from 2 or 3 to 12 or 15 feet above the present sea level, or whether they must be regarded as a local induration of the beach sand and overlying small dunes such as the sandstones exposed at Manapadu and close to the Tiruchendur Temple and already referred to above. I should incline to regard the Valimukkam and other similar sandstones at many places along the Rámnád coast as indurated dune sands like those at Manapad and Tiruchendur, were it not that in Rameswaram island unquestionable evidence exists of a considerable elevation of the land in very recent times, geologically speaking. This evidence is afforded by existence of an upheaved coral reef, very extensive indications of which occur round the northern coast of the island. This reef will be described further on.

The sandstone "quay" along the coast.

A small patch of this hard sandstone fringing the beach was noticed some miles to the westward at Narripurpattanam (Nurripoorputnumchary), while long stretches of

it forming a regular quay wall are to be seen eastward of Kilakarai (Keelakurray) and especially between Muttupettai (Moottupettah) and the spit of land opposite Pamban (Paumben). The rocky barrier or reef which stretches very nearly across the Pamban strait consists also of this sandstone. There is strong geological evidence to prove, that this barrier was once continuous. The sandstone quay runs westwards along the coast on the north side of the Tonitarai spit as far as Pillai Maddam (Pillay Muddum).

Pamben barrier.

The upraised coral reef referred to above is a striking feature of the north coast of Rameswaram (Ramesarum) island, and is worthy of much closer study than the time at my disposal enabled me to bestow upon it. It shows best along the beach beginning a couple of hundred yards west of the zemindar's bungalow, where it forms a little irregular scarp about a yard or 4 feet high against the foot of which the waves break in rough weather. Of its true coral reef origin there can be no possible doubt, as in many places the main mass of the rock consists of great globular meandrinoid corals or of huge cups of a species of Porites which, beyond being bleached by weather action, are very slightly altered, and still remain in the position in which they originally grew. The base of the reef is not exposed as far as I could ascertain, not having been sufficiently upraised along the beach, but in a well-section a little to the south of the Gandhamāna Parvattam Chattiram the thickness of the coral reef exposed above the surface of the water is at least 10 feet, and probably much more. The great swampy flat forming the north lobe, as it were, of Rameswaram island consists, I believe, entirely of this upraised reef hidden only by a thin coating of alluvium or the water of the strongly brackish lagoons which cover the major part of the surface, but do not form a single continuous sheet of water as shown in the map. I came upon masses of coral protruding at intervals through the alluvium in the very centre of the flats north-westward of the great sand hill crowned by the Chattiram just named. The raised reef is very well seen to the north-eastward of Rameswaram town, where it forms a miniature cliff from 3 to 4 or

Raised coral reef on Rameswaram island.

possibly 5 feet high, and continuing along the coast after the latter turns and trends to north-west. Time did not admit of my actually following it up to Pesausee Moondel Point, but I went to within a mile of the point and could see no change in the character of the coast line on examination through a strong field glass. The raised reef shows strongly also along the western side of the flat northward of Ariangundu (Aureyangoondu). The south side of the reef is along the north coast, completely covered up by the great spreads of blown sands which occupy the greater part of the surface of the island. On the east side of the island the reef does not extend close up to the great temple, but stops short abruptly about 300 yards to the north-east, and does not reappear on the coast of the bay south of the temple. South of Pamban town also there were no signs of any upraised coral, nor could I see any indications eastward along the south coast as far as the eye could reach from Coondacaul Moondel Point, while the great south-east spit terminating at the point called on the map Thunnuscody is covered by a double ridge of great blown sand hills. An important series of trial sinkings made by the Port Officer at Pamban right across the island, from north to south, about 2 miles east of the town, in order to test the feasibility of the proposed ship canal,[1] did not reveal any southerly extension of the raised reef. The probability is that it forms a mere narrow strip along the beach from Pamban to Ariangundu, but widens out thence to the north-eastward to form the northern lobe of the island.

Parts of the reef lying between collections (colonies as it were) of the great globular or cup-shaped coral masses form a coarse sandstone made up of broken coral, shells and sand (mostly silicious), a typical coral sandstone.

[1] Through the kindness of Mr. Baker, the Port Officer, I had the opportunity of seeing a series of the rocks obtained by him from the sinkings above referred to. The rocks were all very modern-looking varieties of grit and sandstone imperfectly consolidated, and would certainly offer no obstacle to the cutting of a ship canal if ever that wild scheme should be carried out against the sound advice of the marine authorities. The present channel, if dredged rather deeper, will answer all purposes for the coasting trade, while large ships should never trust themselves to the many dangers of an increasingly shoal sea like Palk's Bay.

At the Pamban end of the raised reef it shows a slight northerly dip, and masses of dead coral apparently *in situ* protrude through the sand below highwater mark. Reefs of living coral fringe the present coast, but these I was unable to examine, so cannot say whether the corals now growing there are specifically allied to those which formed the reef now upraised, but all the mollusca and crustacea I found occurring fossil in the latter belong to species now living in the surrounding sea.

Westward of the Strait the native fishermen assured me the living coral reef extends only as far as Pillai Maddam (Pillay Mudum). This statement, which I had no opportunity of testing, is on the face of it very reasonable, as it is a well ascertained fact that coral reefs never form near the embouchures of large rivers, as the influence of the fresh water flowing into the sea and of the fine silt borne by it is most unfavourable to their growth. A glance at the map will show that coral reefs could not extend westward without coming directly within the influence of the flood waters of the Vaigai. The fishermen, several of whom I cross-examined independently, all agreed that no coral reefs occur further north on the coast of Palks Bay,—a fact borne out by the charts of that region, and due doubtless to the numerous rivers and streams falling into it.

Absence of coral reefs on west side of Palks Bay.

All the small islands occurring along the Tinnevelly and Madura coast appear to consist of sand based upon coral reefs which are largely exposed at low tide. The published large scale charts of Pamban Straits show extensive coral reefs surrounding the five most easterly islands; Moossel, Munnauli, Pullee, Pulleevausel and Cooresuddy. The only one I was able to visit, that on which stands the Tutikorin lighthouse, shows no coral on the surface, which is sandy; but the island immediately to the north supplies large quantities of dead coral, which are used in the town as a rough building stone. Similarly, large quantities of dead coral are brought over to the mainland from several of the central group of *tivus* (Thevoo) or islands along the Madura coast.

Coral reefs off the coast of Tinnevelly and Madura.

It is quite evident from the occurrence of the old coral reef on Rames-

waram island that the latter must have been upraised several feet within a comparatively recent period, but unfortunately there are no data by which to calculate the exact amount of the upheaval. The upheaval which affected Rameswaram island doubtless affected the adjoining mainland, and by upraising the coast exposed the sandstones which have been described above as forming a low wall-like cliff bordering the beach as if a built quay. A piece of evidence connecting the old coral reef directly with the "quay" sandstones is afforded by the occurrence, about half a mile east of Kilakarai (Keelacurray, a small sea-port 26 miles west of Pamban Straits), of an isolated mass of coral exposed in the sandstone cliff. The coral which in appearance and condition is identical with that of the old reef east of Pamban occurs as a rudely conical agglomeration of meandrine masses measuring about a yard in diameter and 4½ feet to 5 feet in height with the sandstone deposited regularly around and over it. This isolated coral mass evidently remains *in situ* as it had grown.

Connection of coral "quay" sandstone at Kilakarai.

It is impossible to resist the speculation that it was this upheaval which gave rise to the formation of what is known to the Hindus as Rama's bridge, and to Mussalmans and Christians as Adam's bridge, the long narrow isthmus which once united Ceylon to India. As soon as the surface of the old reef become dry land, it would begin to arrest the currents, and the surf and wind action around the coasts would throw up the sand dunes which now so thickly cover both Rameswaram island and the long narrow peninsula known as the Tonitoray spit on the western side of Pamban Straits. To this same elevatory action may also safely be attributed the formation of the long line of islets running parallel with the south coast of the Madura district, and trending southward as the Tinnevelly coast is approached. Local tradition, if not history, claims that Rameswaram island was once completely joined to the terra firma on both sides, and that both the Pamban Strait and the various breaches to the eastward have since arisen by a catachysm in the form of a tremendous storm which breached the narrow rocky barrier about the year 1480 A.D. The chief of Ramnad (properly Ramanada-

Formation of Adam's Bridge.

Its destruction.

puram, the city of Rama's district) bears as his highest title the name of Sethupathi or "keeper of the bridge."

From the description given in the "Bengal Pilot" of Adam's bridge, the shoal ridge connecting Rameswaram island with the island of Manar and with Ceylon, it consists of precisely the same gritty calcareous sandstone as the Pamban barrier and the sandstone quay cliff of the Rámnád coast.

Jointing of the sandstone; its effect.

Owing to a system of jointing which crosses the Pamban sandstone barrier nearly at right angles, the action of the waves has broken it up into a series of large flat blocks which so strongly resemble a series of gigantic stepping stones that it is impossible to wonder at the imagination of the author or (in analogy with the Homeric epos) authors of the Ramayana that the rocky ridge was really an old causeway of human construction.

A similar system of jointing shows, though not very distinctly, in the sandstone "quay" cliff at Valimukkam, 36 miles west-by-south of Pamban Straits.

The legend of Rama's bridge.

According to the famous old Hindu epic the construction of this bridge was due to the industry and enterprise of the great army of monkeys and bears led by Rama and his long-tailed friends Sugriva and Hanuman to the invasion of Lanka in their war with Ravana, the king of the demons and the abductor of Sita, Rama's wife. The engineering part of the undertaking was specially entrusted to the monkey Nala, a son of Visvakarma, the famous architect, he having the special power (which would in many cases be much coveted by the commanding R. E. of a modern army) of making blocks of stone to float on the water. There is no apparent reason why the proved up-heaval of Rama's bridge may not have taken place within the semi-mythical time preceding some invasion of the heretical Buddhist kingdom of Lanka (Ceylon) by the Brahmanical Aryans of the mainland and their Dravidian allies.[1]

[1] That such an invasion of the island of Lanka (Ceylon) from the mainland may have taken place in bygone ages along the recently upheaved isthmus is well within the limits of historical probability. Such elevation of the sea bottom would unquestionably be regarded as a miraculous event and be ascribed to superhuman agency, and the fervid imagination of successive Aryan bards may be easily credited with sufficient powers of invention to have evolved all the marvellous mythical details that have been superadded by way of embellishment.

CHAPTER VIII.

THE ALLUVIAL FORMATIONS.

Effects of long continued wet cultivation.

A large area of the region described in this memoir is occupied by the marine and fluviatile alluvia, but there is little to say about them relatively to the superficial extent, as very few sections were met with, and as nearly the whole surface has been greatly altered by the vast scale on which wet cultivation has been carried on for many centuries. Practically the greater part of the alluvial surface is "made ground," the long continued operations of irrigation having in many parts, both of the great and small irrigated valleys, extensively raised the general surface of the country by a process technically known as "warping."

No deep sections.

Of deep sections furnishing any real idea of the beds composing the alluvial deposits in depth, not a single one was met with, nor do any of the rivers afford sections more than a few feet in depth. Over very large tracts of country the surface is completely hidden by paddy-fields or by the waters of the very numerous irrigation tanks, many of which are of very large size.

The soil thrown out of the bottoms of these tanks and piled up to form the "bunds" sometimes affords some clue as to the local character of the superficial alluvium, but even this is very often hidden by the piles of humus and silt that have during the course of ages been thrown out when the tanks have been cleared.

Unaltered alluvium of Pālār.

In some of the smaller rivers, however, the character of the alluvia is not so utterly disguised by cultivation, as for example in the case of the Pālār (the upper part of the Tirupatur river in Madura district). Here the unusually high banks generally reveal a reddish loam derived from the red soil of the gneissic tracts in which it rises to the north-east of the Siru Malai.

Prevailing type of river alluvium.

As far as the great spreads of irrigated cultivation allow of recognition of the true character of the surface beds of the alluvium, there is a very great similarity in composi-

tion in the alluvia generally, as indeed might be reasonably expected from the fact that nearly all the rivers rise on the gneissic tracts in or at the foot of the Southern Ghāts. The prevailing type is a pale red or reddish white or pale brownish sandy loam passing into clay or nearly pure sand in some places.

Exceptional character of the alluvium of Virudupatti river.

An exception to the rule is the alluvium of the Virudupatti (Virdu-putty) river (the main northern tributary of the Vaippār) in North Tinnevelly, which flows through great tracts of typical black soil or regur, and which has covered the low level of its valley with a thick bed of washed-up regur. The alluvium near the mouth of the Vaippār shows the effect of the dark particles of the regur it has carried down, in the dark grey or grey-brown fine silt it has there deposited. Intermediately the sandy and locally somewhat gravelly character of the alluvium prevails as may be well seen to the north-west of Velati Kulam (Vullauticolum).

Alluvium of the Vaigai.

The alluvium of the Vaigai like that of the rivers to the north of it is generally a very sandy loam. Near to Madura it is here and there gravelly, and near Rāmnād extremely sandy. Here and there the beds vary to coarse grit or even fine gravel or quartz and rolled kankar.

Owing to the great offtake of water from the Vaigai by irrigation channels it rapidly dwindles in size below Permagudi and evidently flows only during heavy freshes.

Of the Tambraparni.

The alluvium of the Tambraparni which chiefly drains tracts covered with light red gritty soil is of a pale reddish colour and very sandy. Large quantities of calcareous tufa (pipe kankar and nodular kankar) show in the sandy banks of the river to the south and south-east of Tinnevelly town, and have solidified the otherwise highly sandy beds into a hard and almost rocky consistency. At and above the bridge between Tinnevelly and Palamcotta is a considerable spread of coarse tufaceous conglomerate forming a low platform in the bed of the river on which some small temples have been built; the conglomerate includes much gneiss debris.

The sandy tufa of the banks appears to be highly adapted to contain organic remains, but unfortunately none showed at the time of my visits, though they were very carefully sought for. The tufa looks so likely for them that it is highly desirable the banks should be from time to time carefully examined. No mammalian or reptilian remains were found in any of the fluviatile alluvia in the south. The rivers flowing into the sea south of the Tambraparni carry down sand and fine gravel as sediment, but they also carry very large quantities of calcareous matter in solution, and form large deposits of tufa in their banks or beds. The tufaceous deposits thus formed are mostly massive (sheet kankar), but they all here and there form small quantities of the vermicular and nodular varieties. This latter form is developed to a remarkable extent in the valley of the Nambi-ār opposite to Chittoor, at its junction and its southern tributary, the Anaikulam nullah.

Great tufaceous limestone deposits generally massive in character.

The great spreads of massive alluvial tufa, which are more extensive and remarkable in South Tinnevelly than in any other part of the Indian peninsula that I am acquainted with, deserve special enumeration, and may for convenience be taken in order from north to south :—

More important than in any other southern district.

1. The valley of the Sevandipatti (Shaminthaputty) nullah, 6 miles south-east-by-south of Palamcotta, shows a very large spread of this rock which extends up and down the valley near Sevandipatti village, and shows also very largely above Ayanapatti (Iyanauputty). There is a considerable show of it also to the south of Sevandipatti resting on the gneiss directly.

Tufa deposits at Sevandipatty.

2. The Karseri tank overflow channel shows a great quantity of the massive kankar to the north of the village, and there is a noteworthy show of it also in the southern branch of the nallah which flows past Arasakulam (Urshacolum).

Karseri.

3. On the western side of the great Megnanapuram teri and a little to the westward of Yelluvaraimuki (Yellavoormookee) there is a considerable show of massive

West of the Megnanapuram teri.

tufa which recurs at intervals along the cart track going south-south-eastward to Adayal and Mudalur (Moothaloor). The tufa is largely developed in the bed of the Kārāmeni-ār at the ford.

North of Sathankulam.

4. A great spread of the tufa occurs 3 miles west-north-west of the ford just named opposite the large village of Sathankulam (Shattungcolum) and covers many hundred acres.

At Neddunkulam.

5. At and to the south of Neddunkulam (Neddungcolum), 4 miles west-north-west of Sathankulam, are also notable spreads of massive tufa, a good deal of which appears also still further south in the bed of the Kārāmeni-ār near Pudukulam (not in the map).

West and south of the Sathankulam teri.

6. In the broad shallow valley skirting the western side of the Sathankulam teri occurs the largest development of the massive tufa known in Tinnevelly district. It occupies nearly the whole valley, occurring either on the surface or showing in every well-section visible, and at Vaganeri forms a thick sheet of solid limestone hard enough and compact enough to be thought worth quarrying. It is found continuously down the valley past Selva Marudur (Chella Murdoor) and Iddayangudi to within a mile or so of the west end of the Taruvai lake.

In the valley of the Yellava Odai.

7. Proceeding west hence there are great shows (extensive sheets of limestone) of the tufa in the shallow valley of the Yellava Odai branch of the Nambi-ār at intervals along the course of the stream past Vadacheri (Vuddachary) and Samugarangapuram (Shummoorungaveram), and for several miles up to the branches of the nullah westward of the latter place. The thick bedded massive limestone character of the tufa is very remarkably seen in a small tank close to the old salé (avenue) east of the village. Here too the tufa encloses small segregations of semi-transparent brown chert, having a very flint-like appearance.

At Samugarangapuram.

In the Radapuram valley.

8. South of the valley the tufa recurs again in very large quantity in the Radapuram nullah, especially to the south and south-west of Udayattur (Woothathoor), and

for at least 2 miles southward down the valley. A large show occurs too just above the estuary. The valley of the small stream above the saltpans at Kuthankuli, 3 miles east-north-east of Viziapatti, is also occupied by a large show of massive tufa.

In the valley of the Annam-âr.

9. The valley of the Hannamnadi (Annam aur) is not wanting in tufaceous deposits, but the massive variety is less strikingly developed here.

Curiously enough all this great development of tufa did not yield a single fossil organism, though it was closely searched in many places by myself and a very smart collector. Nor does Bishop Caldwell, who is intimately acquainted with the formation as seen near Iddayangudi and Sathankulam, appear to have been a whit more successful.

Origin of the tufa.

There can be no doubt as to the origin of these extensive and interesting tufa beds; they were formed by the deposition of lime by evaporation of the waters which brought the calcareous matter in solution from more distant sources.

Sources whence the calcareous matter has derived.

What those sources were I am not prepared to say as yet. The gneiss of the low country contains, as far as my observations went, no conspicuous beds of crystalline limestone, nor do many hornblendic beds occur which could have yielded a large supply of lime. It is very probable, however, that such beds do occur on the tops and flanks of the Southern Ghâts, which remain as yet unsurveyed.

Marine alluvia much masked.

Of the marine and estuarine alluvia it is impossible to say much, for they are almost entirely covered up along the Tinnevelly and Madura coasts by the blown sands, whether red or white, which are so largely developed in these regions. Moreover, these formations require much longer study than could be devoted to them during a rapid general survey. The rate at which they increase, the direction in which such increase takes place, or the converse, the rate at which, and the direction from which, they are destroyed by encroachment of the sea, are all questions of considerable interest, but

questions for the answering of which the data have to be collected by careful and often long continued observations. So far as my observations went, I came to the conclusion that nowhere is the sea making any serious encroachments, and that the advance of the land by silting up of shallower parts of the coast has been much greater than the recession by general wear and tear of the coast. A very manifest advance of the alluvium of the Tambraparni delta has taken place during many centuries, as will be shown presently, and the increasing shoalness of Tutikorin harbour shows clearly that the silting up process is still continuing.

Marine erosion small.

It is a well known fact that the coasts of the Indian peninsula are swept by great marine currents running up or down the coast accordingly to the prevailing monsoon, whether it blow from the north-east or south-west. These currents flow with pretty equal force, but owing to the longer duration of the south-west monsoon, it produces the greater effects, and all the rivers flowing into the Bay of Bengal have a tendency to extend their deltas in a north-easterly direction. This tendency, it will be seen, is manifested in the case of the Tambraparni as well as in that of the Vaigai, Cauvery, Vellar, and other more northerly rivers.

Action of the great monsoon coast currents.

The historical proofs of the sea-ward advance of the Tambraparni delta have been worked out with great research and learning by Dr. Caldwell, Missionary Bishop in Tinnevelly district. The proofs of the advance of the delta obtained by the Bishop are the identification of the sites of two famous old seaports—the "Kolkoi Emporium" of the author of the Periplus Mare Erythreum and of the geographer Ptolemy, and the "Cail" of Marco Polo, the famous Venetian traveller. The "Kolkoi" of the Greeks Bishop Caldwell identifies with Korkai, a place now nearly 5 miles inland, which was the capital of the Pandyan kingdom as early as the year 600 B.C. The tradition of its former greatness as the capital and as the centre of the pearl trade was found by

Advance of the Tambraparni delta.

Sites of "Kolkoi" and "Cailth" determined by Bishop Caldwell.

Bishop Caldwell still to linger among the inhabitants, while evidences of its former littoral position are not wanting. As time passed on Korkai decayed because the sea receded, and a new town, Kayal, sprung up on the coast and became known to the world as the "Cail" of Marco Polo. "Cail" was at the time of Marco Polo's visit in 1292 the great emporium of the east coast, and continued so during the middle ages. It also decayed and was forgotten till its site was re-discovered by Bishop Caldwell in 1861 and made public in Colonel H. Yule's beautiful edition of Marco Polo's Travels [1]. From the identification of these two sites it becomes clear that since the time when Ptolemy wrote the coast has gained on the sea by nearly 5 miles, while since the visit of Marco Polo to Kayal in 1292 the coast line had advanced fully 2 miles. Considering the very moderate size of the Tambraparni, the enormous quantity of fine silt retained to raise the general surface of the irrigated valleys and the constant dispersion of the sediment brought down in suspension by the floodwaters of the river by the strong up and down currents prevailing during the alternate monsoons, the rate of growth has certainly been considerable, being just about 18 feet per annum.

The advance of the delta alluvium to the east is very striking in the case of the long spit of land forming the south side of Tutikorin harbour, which now extends out much nearer to the islands east of the harbour than it did when the Trigonometrical Survey was made (in 1828).

To the marine alluvium I reckon some thoroughly unconsolidated beds full of marine and estuarine shells which underlie the long Kalampalli Taruvai or lagoon running northward from Kolasekharapatanam to Tiruchendur. The beds are of a dark clay abounding in Cytherea, Arca, Potamides, &c., &c., all of living species. Two other exposures of beds containing estuarine shells imbedded in dark clay were observed, the one a little west of Melmandai in Tinnevelly, and the other just across the border at Sevalpatti (Shevalputty) in Madura district. In both cases the organic remains had been turned out of the bottoms of

Marine alluvia at Kolasekharapatanam.

At Melmandai and Sevalpatti.

[1] If ever any book deserved the title of Thesaurus Geographicus, it is this noble edition of the Travels of Ser Marco Polo, edited as a labour of love by Colonel Yule, whose acutely critical skill has rescued from unjust obloquy the memory of a really great traveller.

deep *uranis*, or square drinking-water tanks, and in neither was the marine bed seen *in situ*. The Melmandai section yielded a large Cytherea, probably *C. castanea*, while the Sevalputti bed showed numerous specimens of Pyrazus, Cytherea, Cardita, and Ostrea.

Submerged forest at Valimukkam.

One more alluvial deposit deserves to be noticed,—a submerged forest which occurs at the western end of the Valimukkam bay. The forest shows about half a mile north of Valimukkam village in the form of a considerable number of tree stumps standing up out of a bed of soft and tenacious black clay containing oysters and other marine shells imbedded in it. The whole occupies about half an acre in extent, and is just above water at or near high tide. The general appearance of the forest reminded me forcibly of parts of the well-known submerged forest which forms so conspicuous a feature on the beach south of Swansea in South Wales, with this difference that at Valimukkam no leaves or fruits appeared to be preserved, but only the stumps and detached branches and twigs imbedded around the stumps. The wood is of the colour of bog oak, but is in a far softer and more pulpy condition. The specimens I collected were utterly ruined by slight pressure before I could dry them. The disposition of the roots with regard to the stems was not sufficiently characteristic to allow me to recognise the trees represented, but they seemed all very similar. Oysters and other marine shells were, as already mentioned, seen in the black clay, but I picked up on the beach,

A bone ornament out of the forest bed.

or rather out of the ripple of the wavelets, a small bone ornament, a pendant very much like a rude ear pendant, perforated at the smaller end, and with a couple of lines incised all round, each at some little distance from the end. This pendant—the only quasi-prehistoric bone ornament I have found in South India—was, when found, partly surrounded by the black clay and presented every appearance of having been washed out of it very recently. It was very late in the day when I made this find, and I was too weary to make any further search at the time, besides which I had many miles yet to march to a new camp. Unfortunately I had no time to re-visit Valimukkam bay, gladly though I would have done so, for it is a spot that certainly calls for very

close examination as it may yield prehistoric remains of man, if nothing else. The tree stumps have a diameter of from 1½ to 2 feet at base of the bole which is broken off in all cases seen by me. The natives of the place said the stumps were those of a tree called "Kanna Maram" which I have not been able to identify. From the position of this submerged forest two inferences may be drawn, either that there has been a depression of the ground since the forest was in full growth, or (what is less likely) that the trees grew in a hollow below sea level which was fomerly rather inland, for trees of such size were not likely to have grown close to the sea.

South of the muddy bottomed creek which opens into the sea to the north of the village is a very low bank of dark coloured clay, full of Potamides and other littoral marine shells, in very excellent preservation. It is just raised above highwater mark.

CHAPTER IX.

SOILS.

In most regions the soils forming the surface of the country are reckoned as amongst the youngest geological formations recognisable. In Tinnevelly, however, this is certainly not so as concerns one of the two principal varieties of soil, which variety (the red one) is distinctly older than some of the æolian or wind formed rocks.

Two groups, red and black.

The two great groups into which the soils found in Tinnevelly and Madura may be divided are the red and the black. Other varieties occur, but they may safely and conveniently be reckoned to one or other of the great sections. Of the two, the red soils are certainly the older section as will be shown in the next chapter. In point of extension the red soils occupy by far the the larger area, but the area of the black soils is also very large and very continuous in the southern parts of Madura and north-eastern parts of

The cotton soil area.

Tinnevelly. The south of Tirumangalam taluq and south-west of Rámnád zemindari in Madura and

the Satur, and nearly the whole of Ettiapuram zemindari in Tinnevelly are occupied by cotton soil, which also extends over the minor zemindari tracts near the mouth of the Vaipar and well down into the Ottapiddaram taluq. A number of small isolated patches of regur occur scattered over the alluvial beds of the Vaigai valley, and four small but well marked patches are to be seen resting on the gneiss to the south of Palamcotta. These are the Rettiapatti (Ruttiaputty), Sevandipatti (Shaminthaputty), Karseri (Caursary), and Monanjapatti patches, of which the last is the largest but only covers between 5 and 6 square miles of surface.

Outlying patches south of the Tambraparni.

Over the great area occupied by the lateritic and alluvial formations to the north-eastward of the Gundār, which river is, roughly speaking, the eastern boundary of the great regur spread, but few small patches of black soil are to be seen, and all are of small size. Some, if not most of them, are not true regur, or old forest humus, but are the remains of old swamps or jhils, and the bottoms of old irrigation tanks which had become disused and gone to ruin; all these lie in very low positions, often in regular hollows. The old forest humus on the contrary is constantly found in greatest force on the higher grounds and along watersheds. No connection between the regur and the underlying rocks was found anywhere, and in this respect the southern regur agrees perfectly with the great spreads further north in the Carnatic, the Ceded Districts, the Raichur Doab, and the South Mahratta country.

Patches of black soil over the alluvial area east of the Gundār.

In the matter of colour there seems to be a slight difference between the general appearance of the Tinnevelly regur and that of some of the most typical spreads in the Ceded Districts and South Mahratta country; the former is as a rule less intensely black than the latter, and as far as can be judged from rather cursory inspection generally of lesser average thickness. The greatest measured thickness of true regur noted was at Wadda Karai hill south of Satur (Chatur) in Northern Tinnevelly and very nearly in the centre of the great regur areas. Here about 14 feet of pure regur was

Thickness of the regur spreads.

cut through in making an excavation for some railway work.[1] The average thickness is far smaller, and may probably be set down at about 4 feet or rather less. The base of the regur bed is here as in other places often highly calcareous from the presence of a large accumulation of small gravelly kankar.

No fossils in the regur.

No organism of any kind was seen in the regur of Madura and Tinnevelly districts.

Varieties of red soil.

The red soils being generally the product of decomposition *in situ* of underlying ferruginous rocks, vary considerably in character. Over hornblendic and other ferruginous forms of gneiss they are very ferruginous. Near the great and conspicuous beds of granular quartz rock the soil is very gritty and of pale red colour. The soil derived from the decomposition of the highly silicious variety of gneiss, such as that which I have called the Cape Comorin type, is very sandy and of pale reddish colour. A very remarkable formation of deep red loamy soil occurs in a band several miles in width along the foot of the Southern Ghâts, especially in the bay-like recess formed by the great curve of the mountain-range to the north and west of Kuttalam (Courtallum). This is very probably a pluvial deposit brought direct down from the mountain flanks, but it has not been sufficiently examined (because mostly out of the limits of the area surveyed up to the present) to have enabled me to form any positive opinion as to its origin.

Red loam along the base of the Ghâts.

White-ants' nests.

A very remarkable feature connected with the red loamy soil, which covers so much of the surface in the south-western part of Tinnevelly District, is the enormous number of white-ants' (Termites) nests. They are often so numerous as to affect very strikingly the character of the fore-ground of the landscape as their generally large size and bright red colour make them very conspicuous objects. They attain a height very generally of from

[1] I am indebted for this fact to Mr. Spalding, C.E., of the South Indian Railway, who further had the kindness to lay down the course of the railway on my maps with far greater correctness than it is given in the last edition of the Altas sheets.

5 to 8 feet, and occasionally even more, and are two or three shades brighter in colour than the general surface they stand on. Especially conspicuous are they on the tract running south along the foot of the ghâts nearly to Cape Comorin. Termites flourish here as nowhere else in South India to my knowledge.

Denudation by wind.

The surface of all the soils is considerably affected by the violent winds blowing over Tinnevelly during the south-west monsoon, and fresh ploughed fields especially are strongly denuded by the almost incessant south-westerly gales. Great clouds of red sand and dust are carried eastward towards the coast, and there meeting with the fresh sea breeze are dropped and give rise to the red sand hills or teris which will be described further on.

Origin of the teris.

These teris form a line along the coast from near Cape Comorin to a point several miles south-east of Râmnâd. The red dust carried by the south-west monsoon is known to have reddened the sails of coasting craft passing through the Pamban channel; it has also visibly reddened the pale calcareous grit stone (from the Panamparai quarry), of which the great Tiruchendur temple is built.

Great red dust clouds.

During a visit to Kuttalam (Courtallum) in 1869, I noticed on several occasions that the eastern horizon seemed to be on fire, so vividly did the evening sun light up the great clouds of red dust driving before the south-west monsoon gale. Enormous tongues of flame leapt up in the air while the non-illuminated parts of the dust clouds simulated smoke, and the whole scene bore a marvellous resemblance to a terrible forest fire for which, indeed, I mistook it at first, but was informed of its real nature by a friend intimately acquainted with the whole Tinnevelly country. These clouds of red sand and dust are clearly the source of the line of teris which stretches along the Râmnâd coast from Melmandai to Muttupetta.

White and saline soils.

The saliferous white soils which are so common in other districts, though not unknown in Madura and Tinnevelly, are not of sufficient importance to require any special notice here.

CHAPTER X.

ÆOLIAN FORMATIONS.

Blown sands, teris and coast dunes.

There is no part of the south of India in which blown sands play so large and important a part as in Tinnevelly district and along the south coast of Madura. They are of two kinds, differing both in colour and origin—the red sands or teris, and the white which are ordinary coast dunes. Of these the former are the more interesting as well as the more important,—the more interesting as some obscurity has hitherto attached to their origin, the more important as occupying a considerably larger area than do the coast dunes.

Red sands or teris; white sands or coast dunes.

I have already in the foregoing chapter mentioned my belief that the teris owe their orign to the action of the heavy and continuous gales prevailing during the south-west monsoon on the broad belt of deep red loam which skirts the eastern base of the ghāts. By these fierce winds the dry surface of the loam is swept clean, and vast clouds of red dust carried away to the eastward and dropped near the coast. These gales blow in some years for nearly four months without ceasing, so their effect is far greater than that of the north-east monsoon, which is much less violent and often fixes the loose sands by heavy showers. The teri sand is mainly composed of grains of quartz with an admixture of fine red clay dust in very variable quantity. A small and varying percentage of minute grains of magnetic iron is also of general occurrence in the teri sand. From the red colour of the sand one might not unreasonably expect to find a large quantity of garnet sand in it, especially as small garnets are of such extreme commonness in the gneiss of Tinnevelly district. In reality, however, garnet sand does not occur in pure teri sand, at least I have examined scores of specimens from many teris with a pocket lens and never noticed a speck of garnet among the quartz grains.

The red colouring of the quartz grains is entirely superficial, a coating of ferric oxide probably derived from the deep red loam in which

they were originally imbedded, and is easily removed by hydrochloric acid. The grains of sand are well rounded.

From the description given of the red sands of the Nefûd or great desert in northern Arabia, by Palgrave and by Lady Anne Blunt, and quoted in the paper on these sands read before the Geological Society of London (Quar. Jour. Geol. Soc. London 1882, Vol. XXXVIII), it is clear that the teris bear a great resemblance, though on a very much smaller scale to the hills of blown red sand of the Arabian desert. The "fuljes" or horse-shoe shaped hollows do not occur characteristically in the teris, probably because of their much smaller extent and dimensions as compared with the vast ridges and hills in the Nefûd. It is unfortunate that the notes on the Arabian red sand tract contain no hints to help in explaining the origin of such deposits.

Teris known only in two other regions.

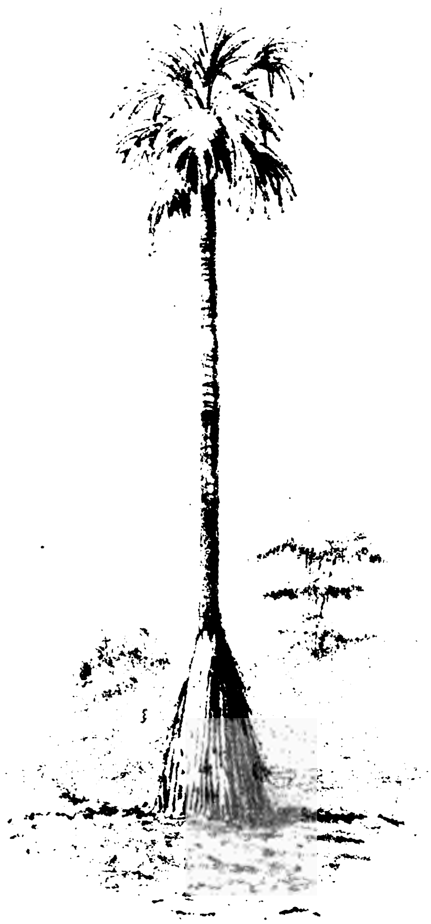
Teris, as the red sand hills are locally termed in Tinnevelly, are unknown in many districts of the south, and have been described by the geological surveyors from only two other districts—the north-western part of Nellore district and the southern part of Travancore.[1] In the former case they are of very small extent, and in the latter they appear to be rapidly losing their character as true moving sands, owing seemingly to the exhaustion from some cause or other of the supply of fresh sand.

Kotapalle teri.

The most southerly teri we have to deal with in Tinnevelly is a narrow strip close to the coast beginning at the extreme south point of the district 5½ miles north-east-by-north of Cape Comorin. The southern part of this strip stretches for nearly a mile south-westward into the Travancore State. This narrow ridge is about as high as the equally narrow ridge of white coast dune which lies between it and the beach. There is hardly any intermixture of the two sands, and the two ridges run on together with hardly any break for some 5 miles to beyond

[1] See Mem. G. S. I., Vol. XVI, p. 101 on the Geology of the East Coast from Lat. 15° N. to Masulipatam, by R. B. Foote, and Records G. S. I., Vol. XVI, p. 31, on the Geology of South Travancore, by R. Bruce Foote, F. G. S., Deputy Superintendent, Geological Survey of India.

the village of Panjell; there the coast dune becomes rather discontinuous, but the teri continues in a very narrow strip skirting the south side of the western limestone plateau at Kudung Kulam. It then becomes rather intermittent, but re-appears feebly to the north of Idindan Karai (Idding Kurra).



Beyond the Viziapatti (Vissiavethee) creek both the coast dune and teri re-appear in force on its north side, and the former rises to the height of some 80 feet above sea level as it approaches the village of Kuttan Kuli (Kothaungculle).

Kuttan Kuli teri.

This teri is of the darkest red colour that I saw, and the sand much the most highly ferruginous, containing as it does a very large percentage of magnetic iron sand. The height of the teri appears to have been considerably greater at one time, but has in parts been greatly and visibly diminished by wind action. Many of the palmyras or fan palms which grow on the teri have had the sand denuded away from around their roots till they now

stand perched on great cones of fibrous roots 6 to 10 feet high, as shown in the diagram sketch.

In several places where the teri has been deeply cut into by wind action, banks of dull Indian-red loam are seen to be exposed, which show distinctly their true æolian origin by the peculiar false bedding, often at very high angles, observable among blown sands. This teri, like most of those in South Travancore which I described in my paper on the geology of South Travancore,[1] is in a state of degradation; only a thin sprinkling of sand on the surface of the teri is now affected by the wind. The main mass has been partially solidified or fixed by the action of rain water percolating from the top aided by the action of heavy showers, which have fallen on the surface and washed the lighter clayey and smaller, though heavier, ferruginous particles down the slopes or into hollows where on drying a fairly hard, often slightly glazed surface of dark red loam has been found. This loam is very fairly fertile, and soon becomes covered with vegetation, which further helps to defend the surface against wind action. The loose sand when deprived of the clayey and finer ferruginous particles, unless unusually coarse in grain, is carried off by extra high winds, or remains on the surface in shallow barren wreaths of lighter red colour. This Kuttan Kuli teri shows more of the fixed loam formation than any of the other teris eastward of Cape Comorin, and less of the rich loamy form of the loose sand.

The teri north of Kuttan Kuli saltpan creek offer no special features worth noting. It runs up to the estuary of the Nambi-ár, and has greatly covered up the shelly grit beds occurring there.

Iddayangudi teri.

Immediately on the east side of the Nambi-ár estuary begins the great Iddayangudi teri which extends north-eastward for fully 15 miles, and increases till it reaches the south end of the Taruvai lake. At its western extremity it is a mere narrow strip, but increases in width after a couple of miles, and then runs on with an average width of about 2 miles till it

[1] On the Geology of South Travancore, by R. Bruce Foote, Deputy Superintendent, Geological Survey of India. Records, G. S. I., Vol. XVI, pt. 1, 1883, page 32.

touches the Taruvai lake. Beyond that it narrows considerably, and to the north-eastward of Sittankudi sinks down into the red sand plain. This sand plain, however, consists equally of the red sand and covers a large area on either side of the Karameni-ár as shown in the map.

The elevation of the eastern part of the Iddayangudi teri is considerable, probably not less than 150 to 180 feet above sea level. How much of this is absolute sand is hard to estimate, but it seems likely that it is in part underlaid by a ridge of marine grits like the Kudung Kulam plateaus, a view which is supported by the fact that an outcrop of limestone was noted about a mile and a quarter east of the Nambiár end of the teri, and at a considerable level (50 or 60 feet) above the alluvial plain to the north.

The Taruvai lake.

The fact that the Taruvai lake is due to the natural dam formed by the sands of the teri which surround it on three sides has already been adverted to (page 5). The view across this lake from the high teri to the south-east of it is a very remarkable one and possibly unique. I came upon it suddenly when crossing the teri northward from the coast between Elanquné and Talai (Periatulla) early in the morning of a beautifully clear day in April 1881, and bitterly regretted I had no sketching materials with me. The immediate foreground consisted of a long slope of pure red sand studded with a few palmyras and banyan trees, and stretching down to the blue and silvery surface of the lake which was framed to the north and west by the rich and varied greens of the great forest of palm trees so eminently characteristic of south-eastern Tinnevelly. The south side of the lake was formed by the continuation of the red sand slope broken here and there by clumps of palmyras and small banyan trees which seem to thrive very fairly in the sands. In the mid-distance rose above the palm forest a line of high red sand hills, the Ittamoli or Sathan Kulam teri, then a widespread plain also densely covered with palm forest stretching away 20 miles to the foot of the mountains, of which a glorious chain stood up blue and sharply cut with

the peak of Mahendragiri and its magnificent twin cliffs[1] in the centre. Nowhere else have I seen a landscape in which pure and intense red forms such bold contrasts to the green of the mid-distance and the varying blue tints of the back ground and sky. It must be seen to be realised. The red sand of the teris is of a very vivid colour in general, especially when seen in bright sunlight at a moderate distance. On this occasion the sands in the foreground could only have been represented by shades of subdued scarlet, those in the mid-distance by slightly paler scarlet with a dash of rose madder. The whole scene was one of extraordinary brilliancy and beauty.[2]

Ittamoli or Sathan Kulam teri.

The Ittamoli or Sathan Kulam teri is, though not quite the largest, certainly the finest and most picturesque of all the teris. It is also (I believe) the highest, having an elevation of 219 feet at the Great Trigonometrical Station in its centre. Its superficial extent cannot be much less than 20 square miles; so there is abundant room for the display of all the peculiarities of æolian formation. The movements of the sand would appear to be more active here than in any of the other teris. Certainly at the time of my visit to its highest part I noticed many more freshly-formed drifts than in any of the other teris. The sand waves on the higher parts of the teri do not average more than, if so much as, 20 feet in height, and are far from regular in shape or direction of advance; the distribution of the sand in falling over being evidently much affected by eddies in the wind.

I have already mentioned above (page 63) that I was unable to find the inlier of marine limestone mentioned and mapped by Bishop Caldwell, which was doubtless covered by one of the sand waves I saw. The approximate locality for that inlier to be found at is not very

[1] These two splendid cliffs which are bare faces of gneiss 1,800 to 2,000 feet in sheer heights are really the east end of a great spur, but as seen from the east seem part of Mahendragiri itself.

[2] In the hope of getting a sketch of this very remarkable landscape, I re-visited it in the beginnnig of this year, but the weather was unpropitious and dull, and the mountains showed very faintly; so half the charm of the view was gone.

far from the highest part of the teri, it follows, therefore, that the teri has been deposited upon and around a mass of marine limestone elevated not much less than 200 feet above sea level, consequently the true thickness of the mass of red sand is certainly in parts very much less than the apparent mass.

Megnanapuram teri or Kudirai Moli.

The great teri north of Megnanapuram, also known as the Kudirai Moli, is rather larger in superficial extent than the Ittamoli teri just described, but it is less elevated, and showed at the time of my visits (in January 1883) many fewer signs of recent movement of the sandwaves. It also appeared to me of a rather less vividly red colour than any of the other large teris.

Thickness of the teri.

Here too there are signs that the sand rests in part at least on an elevated mass of the marine sandstone series. Still I think it will be safe to estimate the maximum thickness of the sand at somewhat over 100 feet.

Drainage of the teri.

Kudirai Moli, as this teri is called on the map accompanying the District Manual, shows markedly a phenomenon common to all the teris, namely, the issuing from their base of springs of some size due to the percolation from above of all the rain falling on the surface. It is only in exceptionally heavy rains that any water flows off the surface of the sands; all other rainfall is absorbed at once and flows out around the base quietly and continuously. Along the northern side of the Kudirai Moli advantage is taken of these springs, and channels are excavated to some depth, sometimes as much as 12 feet or more, to meet these springs and conduct their water for irrigation purposes to fields and gardens in the neighbourhood. These channel sections reveal that in many places the percolation of the rain water has given rise to a cementation of the mass of ferruginous and silicious particles into a quasi-lateritic agglomerate.

Teris north of the Tambraparni.

The teris north of the Tambraparni river are quite small and unimportant comparatively speaking. The little teri north of Panavalli church is low and ill-defined. The next to the northward, which lies not far west of the large mis-

sionary station (S. P. G.) at Sawyerpuram, is like the Kuttankuli teri in a wasting condition. It is of considerable interest, however, from the fact that it contains proof of the residence of pre-historic man in that quarter. On the southern side of the centre of the teri is a hard loamy surface exposed by the removal of some 15 or 16 feet of the blown sand. On this surface I had the good fortune to find numerous small cores and flakes of a reddish chert quite foreign to these parts, and with them fragments of burnt pottery showing a distinct pattern. A few flakes of limpid quartz were also found. The cores are of the same pattern as those found near by Jabalpur and described by Sir Charles Lyell. This teri is highly ferruginous.

Sawyerpuram teri.

Find of chert cores.

A considerable spread of quite low hillocks of deep red sandy loam is traversed by the road from Palamcotta to Tuticorin, after crossing the small Madagiri river.

To the north-west of Tuticorin the road to Ettiapuram passes through a tract of low wavy mounds of loamy red soil which have a rather teri-like aspect.

North of the Malletar Odai or Veddanattam river the line of teris rends north-eastward and continues more or less parallel to the coast to its further end.

The Kollatur and the western part of the Melmandai (Mailmuntha) teris, though quite unmistakable in colour, are generally very low and greatly overgrown with thorny scrub jungle. The north-eastern end of the Melmandai teri is considerably more elevated, and though much jungle covered, there are several wreaths of brilliant red sand showing over the jungle.

Kollatur and Melmandai teris.

The Sivalpatti (Shevelputty) teri is by much the largest in the Madura country, but is much overgrown with thorny scrub. The south-westerly corner, however, close to the village and crowned by a small American Mission chapel, forms a conspicuous ridge of very ferruginous red sand, from

Sivalpatti teri.

which a very extensive view is obtained over the great alluvial flat to the north. The northerly ridge of the Sivalpatti teri continues high and well marked for some miles, but then sinks down with the alluvial plain. Sivalpatti village is incorrectly shown in the map; it stands on the east side of the Up-Ar (Hoop Aur) nullah.

The small teris at Sailagudi (Shoylagoody) on the banks of the Gund-ār and at Selvanallur (Mala Shelvanellor) require no special notice, but the Rajakapallem teri requires some attention from its remarkable length and narrowness, and also from the fact that the colour and constituents of the sand ridge show that the great purity of the red sand prevails no longer as the source of the same is left behind more and more. The sand has become considerably calcareous, and a tendency to solidification by concretion with a calcareous cement becomes visible. The very vivid red colour is decreasing, and this decrease continues as the ridge is followed past Yeravadi to Kila Karai, while to the eastward of the Kova Kulam (Covacolum) creek the teri sands gradually become paler and paler, and finally can no longer be distinguished from the impure coast dune sand of the Tonitorai peninsula. The most easterly sand hill that I have mapped as a teri is a ridge some 4 miles south-east of Rāmnād, the sand of which can only be termed reddish.

Rajakapallem teri.

The only organic remains found in connection with the teris were some fragments of calcified exogenous wood discovered on an exposed mass of hard red loam in the hollow between two great sandwaves on the high teri about 2½ miles east-south-east of Nazareth. The fossil wood was accompanied by some fossil shells and casts of the living *Helix vittata*, the common snail of this part of India.

Fossil wood, &c., in a teri.

That the advance of the teri sands has from time to time caused mischief by burying fields and gardens and occasionally houses, is well known, but much has been done to check its advances by extensive planting, and much more may yet be done; it may not be too much to say, that as the population

Movements of the teris.

increases, the whole waste will eventually be reclaimed, for the teris are by no means barren sand heaps. Mixed with the silicious grains is very frequently a percentage of fine red clayey matter large enough to make in the presence of sufficient water a very fairly productive soil.

Rate of advance of teris.

The rate of advance of the sands on the Ittamoli (Sathankulam) teri has been conputed by Lieutenant-Colonel Branfill, Deputy Superintendent, Great Trigonometrical Survey, to have been 1,000 yards, or nearly 17 yards a year during the 60 years which elapsed since Colonel Lambton (in 1808-9) fixed his Trigonometrical Station (Red Hill Station of Atlas sheet) on the top of the teri. In the four years, however, from 1869 to 1874, the advance was only at the rate of 6 yards a year. In both series the direction of the advance was the same, namely, towards the east-south-east.

Coast dunes at Manapād.

The greatest developments of the coast dune sands in Tinnevelly has been along the coast from a village called Talai to Manapād point. Here the sands, which form a high ridge and are extremely calcareous from the great quantity of comminuted shells they contain, have been to a great extent solidified in some places perfectly, and others imperfectly. In many places the action of the high westerly winds has carried away the loose sand from the consolidated part and left the latter standing up in strangely shaped masses. This process of consolidation has gone on much more strongly near the eastern end of the ridge probably because exposed to heavy spray drifts during storms in both monsoons. The rock formed here, which often contains marine shells as well as specimens of *Helix vittata*, is hard enough to be used for building purposes.

Consolidation of sands.

The Manapād sand ridge must be fully 100 feet high or more. The sands on the north side of the ridge are quite unconsolidated, and in the village of Manapādu (Manah paud) they have been heaped up amongst the houses and churches in such a way as to render some of them almost untenantable. Some small buildings are said to be quite

covered, and among them the grave of the celebrated Jesuit Missionary, Father Besche, who, though an Italian, became so proficient in the Tamil language as to write in it poetry of such excellence as to give him a high rank among Tamil poets.

Another important coast dune is that at Tiruchendur, 9 miles to the north-north-east, on and against which has been built the famous Subramania temple, the most important in the district, whose great gopuram is a landmark both by sea and land for many miles around.

Tiruchendur dunes.

The sand-hill rises fully 50 feet above sea level, and has been considerably consolidated by infiltration of calciferous water, and at its seaward end has been converted into a coarse sandstone of sufficient stability to form a low but well marked headland which offers some resistance to the action of the surf that breaks at its foot. It has been cut into a steep cliff, at the base of which is exposed a bed of hard gritty sandstone of similar character to that forming the "quay" along the Madura coast as described above.

The dunes south of Tiruchendur for about 2 miles are much higher than usual, but show no signs of consolidation.

The coast dunes along the Madura coast nowhere attain any great height; very few, if any, attain an elevation of 50 feet. The highest noted was the dune on the south side of the salt-water lake opposite to Nallatanir Tivu (Nallattume Thevoo). Some large sand-hills occur also to the south of Ervadi (Yervaudy), and to the west of Kila Karai. A great many sand-hills occur at Rameswaram island, and in fact occupy the greater part of the surface there. A great part of them is too much overgrown by trees and shrubs to allow of any appreciable movement, but in the southern part of the island there is a considerable extent of moving sands, while the long spit running out to the south-east is occupied by a double line of high sand-hills which are perfectly bare of vegetation, and therefore subject to the influence of any high wind that blows.

Dunes of the Madura coast,

And of Rameswaram island.

The highest point on the island is the great sand-hill north of the

town on which stands the Gandhamāna Parwattam Mantapa, from which an extensive view is obtained, and a very good idea of the extent of upraised coral reef. Some small islets, apparently part of the Adam's bridge shoal, were seen to eastward.

CHAPTER XI.

ECONOMIC GEOLOGY.

The enumeration of the economic mineral products met with in the Madura and Tinnevelly districts may unfortunately be comprised within a few pages; in other words, both districts are poor in valuable minerals.

Iron the only metal.

The metallic minerals are represented by iron ore only, and that not of the highest class. Abundance of an earthy form of hæmatite is to be found in the lateritic rocks in the northern parts of our area, and there are traces of a considerable smelting industry having been carried on at no remote period at Ayangudi in the southern part of Pudu Kottai State (see page 46). The ore treated is clayey red or brown hæmatite of fair quality, of which an endless supply could be obtained in any of the lateritic tracts north of the Vaigai. I

Old smelting industry at Ayangudi.

could find out nothing about the smelting industry at Ayangudi, which seemed to have been entirely forgotten by the people now living. The country is too bare of forest now to support even the small native smelting works, but it is well known that at the time of the conclusion of the Poligar war in 1803, this region was covered with very extensive jungles through which our armies had to cut roads with great labour, *e.g.*, at the siege of Kalayar Kovil.

No signs of any iron smelting industry on a large scale, even for native smelters, were seen any where further south, nor did my enquiries obtain me any information of such having existed elsewhere.

The other economic minerals used have been building stones and

Building stones.

limestones for making cements and mortars. Of the former there is no lack in most of the gneissic regions, and for coarse work a supply is obtainable in many of the north-

ern laterite tracts, where the hard and massive forms of the rock abound and have been largely used for many purposes, such as walls of temples, and the revetting of the teppa kulams, or temple tanks.

Laterite as a building stone.

Massive laterite was used almost exclusively in building the fine old fort at Kilanelli Kotai, also the fort at Arrantangi in Tanjore district (see page 46). It has also been largely used as road material.

In the Shenkarai and Shahkotai tracts are lateritic quarries in which masses are raised measuring as much as $8' \times 1\frac{1}{2}' \times 1'$, a very large size for a lateritic stone. This is by far the best and most reliable form of laterite I have seen in South India.

The gneisses furnish a great variety of stone, but the most valued forms are the reddish or pinkish-grey granitoid varieties. The quarries most resorted to in Madura for example are those of Tiruparai-Kundram at base of the Sikandur Malai, whence the stone used in building the great Minakashi temple has been procured. Not only is the stone a very handsome one, with its pink and grey bandings, but if well selected it is susceptible of being carved with great delicacy. Masses of almost any size can be quarried.

Gneisses as building stones.

Quarry on the Sikandar Malai.

The westerly extension of the Sikandar Malai beds has been considerably quarried close to the village called Ambalathandi in the map.

About 27 miles to the southward of Madura are the quarries of Arupukotai, where a rich red granite gneiss of great beauty is largely raised, being in much request. Masses of great length, even of 18 to 20 feet, have been procured. The stone if polished would equal the very finest Peterhead granite in beauty.

At and near Arupukotai.

A similar but rather duller red stone has been worked at the Moonooroopoor quarry, 6 miles north-east of the last named. A very handsome, rather purplish-grey massive granite gneiss is procurable from the quarries at Shayalpatti (Shoilputty), 2 miles north-west of Moonooroopoor rock. Handsome banded gneiss of high quality has also been quarried on a rocky hill a mile west of Tirushulai (Teruchooly).

At Kotai parai.

Massive black hornblendic gneiss is quarried at Kotaiparai (Koteaupauræ) hill, 6 miles west-by-south of Arupukotai. At the time of my visit a large monolithic male figure some 10 to 12 feet long was lying in the quarry, having, as I was told, been rejected for some reason or other by the authorities of the Rameswaram temple for whom it had been carved. The figure, which represented one of the minor divinities worshipped at Rameswaram, was a fine specimen of stone cutting, and showed the fitness of the rock for such purposes.

At Puliar patti.

To return northward for a little there is a large quarry of handsome banded gneiss at Puliarpatti, 4 miles east by north of Tripatur; blocks of large size can be quarried here. I measured some nearly 30 feet in length. As the rock is easily quarried and moderate in price as well as very handsome, it is in demand. Large pillars for temple cloisters or for mantapams measuring 12′ × 3′ × 1′ 6″, and roughly dressed, were procurable for Rs. 30 on the spot.

Carved and polished stones at Madura.

The fine black polished pillars in the Judge's room in Tirumal Naik's palace in Madura, and the dark hornblendic rock out of which are carved some of the very elaborate and often bold statues in the great Pagoda, must have been brought from quarries I did not come across, as I saw no rock of the kind. I made personal enquiries of the head temple trustee as to whence they came, but he either could not, or would not, give me any information on the point. Some of the finest and boldest carvings, both of statues and scroll work that can be met with in Southern India, are to be seen at the Avadiar Kovil (temple) in the southernmost corner of Tanjore district, which just comes into the limits of the map accompanying this memoir. The great mantapam in front of the temple gate is an architectural work of great beauty and noble proportions, and well worth the attention of photographic artists, though unfortunately much out of the beaten tract and therefore but very little known. The stone used here is said to have been brought from Tirumayam (Trimiem) and Trikonem in

At Avadiar Kovil.

Pudukotai State, but is more hornblendic than any of the rocks seen at those places.

Turning to the south again, the beauty of the pale highly silicious granite gneisses of the Cape Comorin type, such as those quarried near Kalligudi Chatram Railway Station and at the Waddukarai rock near Satur, have already been mentioned above (page 23).

In many places in both districts are the beds of granular quartz rock quarried but only for road material or for rough stone, as it is perfectly useless for any other purposes.

Crystalline limestone of Pantalagudi, &c.

No use, except as rough stone, appears to be made of the fine crystalline limestone at Pantalagudi (page 21), 35 miles south of Madura, nor of any of the other fine limestone beds at Tirumal (14 miles south-south-west of Madura) or at Shenkotai, 8 miles south of Pantalagudi, though these beds could easily be made to yield an inexhaustible supply of beautiful pale grey, grey and pink, pink, and pink and green marble of high quality.

The Pantalagudi marble had been noticed already in pre-historic times, as blocks of it had been carried at least 3 miles distance to be used with blocks of gneiss and others of laterite in the construction of a group of Kurumbar rings lying to the south-west of Pantalagudi.

Coarse schistose sandtone flags used for Menhirs.

The hard sandstone of supposedly Cuddalore age, which lies a couple of miles south-east of Sivaganga, is quarried to some extent as a building stone. The very coarse ferruginous, quasi schistose, sandstone which occurs on the west side of the Sivaganga laterite tract and about north-east of Mannambakkam has been used in long pointed slabs to form small "menhirs" or upright stones in the centres of some Kurumbar rings, the other stones of which consist of rude laterite blocks. The tallest of these three menhirs stands about 7 feet out of the ground.

Marine sandstones and gritty beds.

The gritty calcareous sandstones and the shelly limestones belonging to the recent marine series are quarried in many places, some of which have already been incidentally named, but others have now to be enumerated. Beginning at

Rameswaram, with the exception of a few statues made of gneiss, the whole of the great gateways and cloisters which surround the inner temple are built of such sandstones. The fine-grained sandstone, of small blocks of which the east and west gopuras are built, I did not see *in situ*, nor did I find out whence it was procured, but the coarser gritty form of which many of the pillars in the cloisters are made, as well as much of the flagging, bears a very striking likeness to the rocks on the Valimukkam spit (page 68) where an immense quantity of quarrying has been done, and the stone raised shipped away. The places left in the rock there are very frequently such just in shape and size as would have been made in quarrying the cloister pillar blocks. Similar quarry remains were noticed in the sandstone "quay" east of Kila Karai, but on a much smaller scale and in an inferior kind of rock.

Rameswaram temple.

Quarries at Valimukkam.

The fine blocks of gritty calcareous sandstone raised at Vedanattam to the north of Tuticorin are largely used for building in that town. Fine cattle troughs, &c., &c., are also made at the quarries.

At Vedanattam.

For rough building purposes the Tutikorin people employ large quantities of coral rock which is procured from the island to the north of the lighthouse.

The fine cream-coloured or brownish calcareous sandstone or grits obtained at Panamparai on the south-western side of the great Megnanapuram church has been employed in the construction of the great temple at Tiruchendur already referred to, and also in the building of the stately gothic church designed and erected at Megnanapuram by the late Revd. J. Thomas of the Church Missionary Society. The same quarry is now furnishing very fine stones for the rebuilding of the church at Mudalur by the Revd. H. B. Norman of the S. P. G.

At Panamparai.

When completed, this will be the third large gothic church built in this quarter, the second being the fine church built at Iddayangudi by

Bishop Caldwell from the cream-coloured calcareous grit quarried near Thissianvillai on the south side of the great Ittamoliteri. These three noble churches show the capabilities of the stone used to great advantage, for they are buildings of which even large towns in England might justly feel proud. The churches are built almost entirely of stone.

At Thissianvillai.

The last locality to be mentioned where these marine beds are being quarried is at Kudungkulam, where some of the stone is equal to that from the quarries just named. Only smaller objects, such as verandah posts or lamp posts, door frames and steps, troughs, &c., &c., were being turned out at the time of my visit.

At Kudungkulam.

The massive tufa, of which so much was said above, is only used as rough stone, or for burning into lime. Elsewhere lime is obtained by burning the nodular tufa or kankar.

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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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THE GEOLOGICAL SURVEY OF INDIA.

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PREFACE.

The present is, in all probability, the last description of geological surveying in India that I shall ever write. After taking part in the work of the Geological Survey for more than twenty-seven years, I am reluctantly compelled to forego the hope of aiding any longer in its labours. So much exploration and study are necessary before the many difficult problems presented by Indian geology can be solved, even to the imperfect extent that similar problems have been solved in countries where observers are more numerous, and physical difficulties less, that it is some satisfaction to reflect upon the progress that has been made, and to contrast our present knowledge of Indian geology with that which was available a quarter of a century ago. But although to any geologist now entering upon the study of Indian formations for the first time the amount of accumulated information may appear imposing, to one who has assisted in the research, and is now quitting the field, the links that are wanting to complete the chain appear more numerous than those that have been forged, and the gaps are more conspicuous than the finished work.

The present memoir is an account of an attempt to forge one of these missing links, and to apply the knowledge of tertiary rocks gained in one part of the country, Sind, to

throw light upon the structure of a more difficult region, the Punjab.

The study of the Indian tertiaries was unfortunately commenced at the wrong end. This was due neither to error nor ignorance, but was partly caused by the arrangements for geological work depending largely upon the progress of topographical surveying, and partly by the necessity of exploring particular tracts of country in order to ascertain the distribution of valuable minerals. For these reasons, the confused and imperfect series of tertiary rocks exposed in Burmah, the Assam Hills, the North-West Himalayas, and the Punjab, came under the notice of the Survey before the superb and richly fossiliferous sections of the Sind hills had been studied. Now that, at length, some knowledge of the Sind tertiary formations has been attained, it is essential that the knowledge procured should be applied to the classification of the rocks in the other tertiary regions of India.

The process is two-fold. The palæontological collections from Sind require careful study and description, and the stratigraphical divisions require tracing in the field in connexion with those in neighbouring parts of the country. In the former branch of the subject a little has been done already. Professor P. Martin Duncan has very kindly described and figured the corals of the Sind rocks, and is now engaged, with the co-operation of Mr. Percy Sladen, in describing the still more important collection of *Echinoidea* from the same beds. To these two gentlemen Indian geologists are deeply indebted. But until the fossil mollusca of Sind have been determined and figured, the palæontological materials for the study of the Indian tertiaries will continue

to be not only imperfect but misleading. The only important contribution to the subject, the well known work of Messrs. D'Archiac and Haime on Indian nummulitic fossils, not only includes forms from lower and upper eocene, oligocene, and miocene beds, all attributed to the eocene, but, owing to the very imperfect state of preservation in which many of the specimens were, neither the figures nor descriptions of a considerable proportion of the species are satisfactory. I am indebted to Professor Martin Duncan for especially calling my attention to this circumstance. There is unfortunately no question but that many of the identifications of Indian tertiary fossils made by the aid of Messrs. D'Archiac and Haime's work are erroneous, and amongst the names that will require revision are some of those contained in the lists drawn up by Mr. Fedden and myself, and published as an appendix to the description of the geology of Western Sind in the seventeenth volume of these memoirs. Most of the lists of tertiary invertebrata quoted in the Manual of the Geology of India suffer from the same disadvantage.

The season's work, of which the present memoir gives an account, was devoted mainly to the other branch of the process, to the endeavour to trace a connexion between the tertiary deposits of Sind and those of the Punjab by following the rocks themselves to the northward. The results, as will be seen, were fairly successful, and in the case of the Lower Manchhar or Siwalik beds some interesting additions were made to the fauna previously known. At the same time a rough geological sketch was made of a considerable tract of country, not always very easy of access, along the

frontier of British India. This tract had hitherto been represented by a blank upon the geological map.

In the course of the season's work it was necessary to traverse a portion of the ground in the Bolán Pass and near Quetta, recently described by Mr. Griesbach in the eighteenth volume of these memoirs. On some geological questions, I have come to conclusions differing from his, and I have, in the following pages, explained the differences between us and my reasons for not concurring in Mr. Griesbach's opinions. Some surprise has been expressed in Europe at the circumstance that members of the Indian Geological Survey publish criticisms of each other's work; it is therefore necessary to explain that the opportunities for doing so are comparatively rare; that it is very unusual for one surveyor to examine the work of another immediately after an account of the latter has appeared, and also that, owing to the size of the country, and to many parts of it being difficult of access, anything like efficient supervision of the work is impracticable, whilst there are no independent scientific observers, as in Europe, to call attention to mistakes and to enforce the necessity of caution in expressing opinions. In fact the want of intelligent external criticism is one of the most serious disadvantages under which the Indian Survey labours, and the only method of compensating for this drawback, and of obtaining the scientific advantages that always result from a discussion of different views, is for Indian Surveyors to criticise each other's work and to notice all points on which difference of opinion exists. Even if no other advantage be gained, future observers, by being placed in possession of both sides of the question, will

have an opportunity of ascertaining by further research which opinion is better founded.

It is scarcely necessary to say that geological surveying on the frontier of India and beyond it, especially around the Punjab, is only practicable with much more assistance from the Civil and Military authorities than is requisite in more settled parts of the country. I was greatly indebted, not only for official assistance, but for much personal kindness, to the officers of the Punjab Government and of the Baluchistan Agency, and especially to Sir R. Egerton, Lieutenant-Governor of the Punjab, Colonel Ommaney, the Commissioner of the Derajat, and Mr. Fryer, Deputy Commissioner of Dera Ghazi Khan. I am under at least equal obligations to my old friend Sir O. B. St. John and to Colonel Waterfield, who occupied in succession the post of Political Agent to the Governor General at Quetta, and to Mr. Bruce, Assistant Political Agent at Jacobabad. It would make too long a list to mention all by name to whom I am indebted, but I must express my acknowledgments to General Edwardes of Quetta, Colonel Chambers, 24th Bombay Native Infantry, who commanded at Kach, and, above all, Colonel Lance, 2nd Punjab Cavalry, of Dera Ghazi Khan.

I am also indebted to my friend and former colleague Mr. A. B. Wynne for preparing the drawings used for the frontispiece and some of the sections, and to Dr. H. Woodward of the British Museum for assistance in the illustrations of Siwalik mollusca.

LONDON; W. T. BLANFORD.
October 1883.

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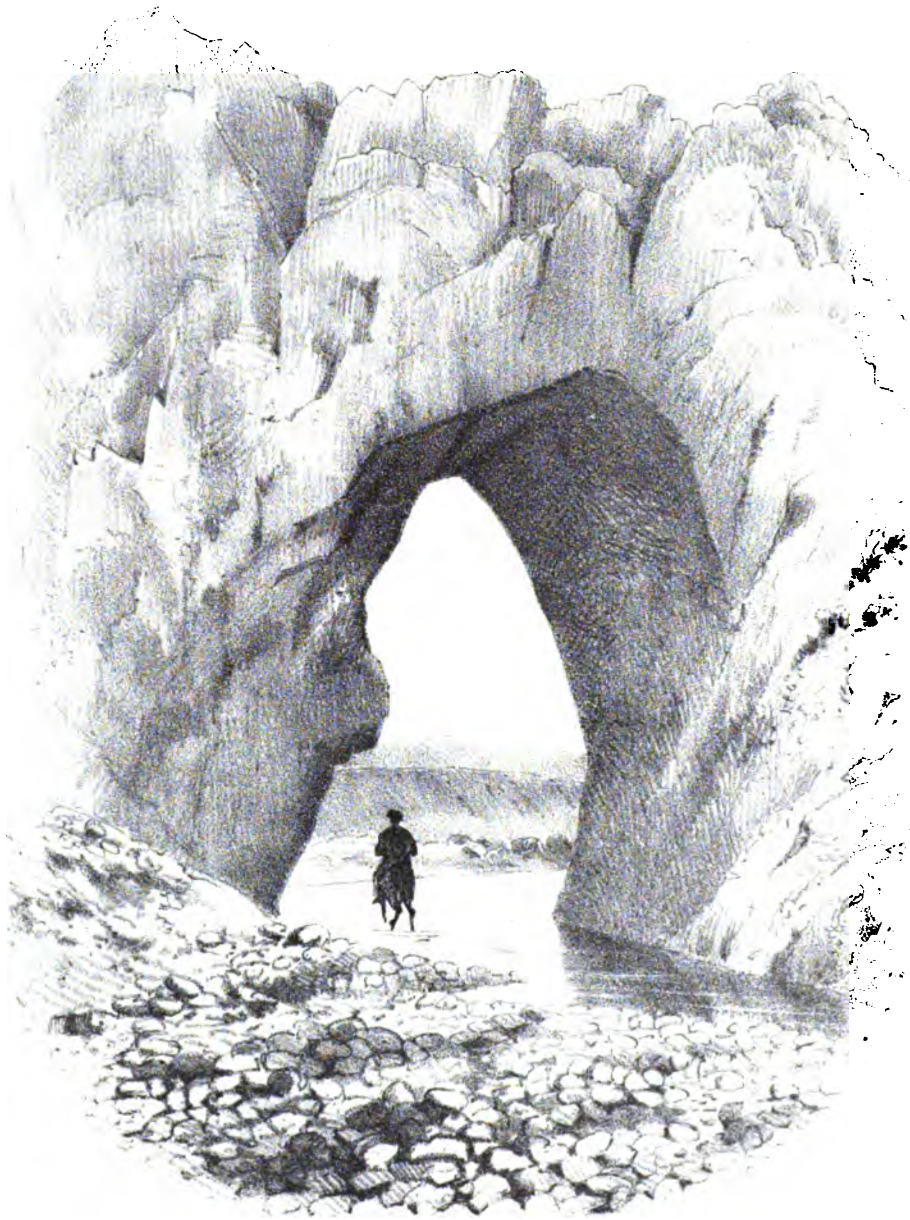

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NATURAL ARCH THROUGH A RIDGE OF SIWALIK CONGLOMERATE NEAR SANGSILA, BUGTI HILLS.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

GEOLOGICAL NOTES ON THE HILLS IN THE NEIGHBOURHOOD OF THE SIND AND PUNJAB FRONTIER BETWEEN QUETTA AND DERA GHAZI KHAN, *by* W. T. BLANFORD, F.R.S., &c., *Deputy Superintendent, Geological Survey.*

PART I.—GENERAL.

CHAPTER I.

INTRODUCTION.—PREVIOUS OBSERVERS.

Plan of season's work.

The principal object of the field work done by me in the season 1881-82 was to trace northward the well marked series of tertiary rocks, of which the age has been determined by the occurrence of marine fossils at several different horizons in Sind, and to ascertain how far the classification established in that province could be applied to the tertiary beds of the Punjab. As is well known, in consequence of the absence of marine fossils, or of any well marked subdivisions, it has hitherto been found impracticable, in the last named area, to determine the age of the beds above the eocene,

and their relations to corresponding strata in other countries, with sufficient exactitude.

The route I followed was the following:—

Starting from Sibi, the present terminus of the railway, I marched by the Bolán route to Quetta, and after a few days spent at that place I returned by the Harnai road to Sibi again. I thence proceeded to Jacobabad, skirting the western border of the Bugti hills, and again, leaving Jacobabad, I marched *viá* Bugti Dera,[1] in the heart of the Bugti country, Siah Tank, the Sham plain and the Cháchar[2] Pass to Harrand in the Southern Deraját, and near the south-eastern extremity of the Punjab. From Harrand I proceeded to examine the Sulemán range, and I had marched northward along its eastern watershed as far as Mangrotha, 50 miles north of Dera Ghâzi Khán, when I was compelled by illness to leave the field, and I was unable to resume work. Had I not been thus interrupted I might have examined the eastern slopes of the Sulemán range for about 30 miles further north, as far as the frontier of Dera Ismail Khán. South of this frontier the tribes inhabiting the hills are friendly Baluchis, but to the northward all the hill tract is occupied by Pathán tribes, and any attempt to enter the country without a very considerable military force would certainly prove a failure. Very little additional information as to the Sulemán range could consequently have been gained, and time would not have sufficed in any case for the examination of the Northern Punjab.

Route followed.

Difficulty of examining northern Sulemán area.

The tract thus traversed is the border of the Baluch and Afghan highlands. To the eastward the plain of the Indus valley is nearly coterminous with the British frontier, the foot of the hills being, throughout the southern Deraját (or districts of Dera Ismail Khán and Dera Ghâzi Khán), the limit of British territory. To the westward a considerable tract of plain, includ-

Geography of area examined.

[1] Called Seháf or Bugti Dera on the accompanying map. The first name properly applies to the surrounding district, not to the fort and small town.

[2] Cachar on map.

ing all the Kachhi or flat country around Sibi, Bhág, Gandáva, &c., belongs to Baluchistan. The Kachhi may be described as a great gulf-like expanse of level ground running north from Sind between the hill ranges of Baluchistan. With the exception of a small portion of Southern Afghanistan, all the area examined is outside the British frontier.

Tracts left unvisited.

Owing to want of time it was impossible to examine two tracts of country in the neighbourhood of the route, and a knowledge of the geology of these areas is still a desideratum. One is the range of hills along the western side of Kachhi between the northern boundary of Sind and the entrance to the Bolán Pass. The other is the Mari country east and north-east of Sibi. Some sulphur mines occur in the former locality near Bágh, and it is possible that mesozoic rocks are found, for Dr. Bellew[1] states that in the Miloh (Mula) Pass, 20 miles beyond Gandáva on the road to Khozdár, "every pebble and every rock is full of madrepores, *ammonites*, *belemnites*, oysters, and other marine fossils." In the Mari hills there is a reported petroleum locality. The ground between the Bolán and Harnai routes still requires examination, although an attempt is made in the accompanying map to suggest the probable distribution of the different systems of rocks.

Petroleum of Mari hills.

Results of season's work.

How far the objects of the season's work were attained will be shown at some length in the following pages. The principal results, however, may be briefly summarized. It should be remembered that the sequence of tertiary and upper cretaceous strata in Sind,[2] and their age, according to the geological scale adopted in Europe, are the following:—

Sequence of beds in Sind

1.	Manchhar or Siwalik	Upper	Pliocene.
		Lower	Upper Miocene.
2.	Gáj		Miocene.

[1] From the Indus to the Tigris, p. 40. The observations were made on a hurried journey, and there is, I think, a possibility that eocene fossils may have been mistaken for ammonites and belemnites, for the author does not profess any special knowledge of palæontology.

[2] Mem. G. S. I., Vol. XVII, Pt. 1, p. 32, and Manual of the Geology of India, p. 447.

3. Nari	. Upper	. Lower Miocene?
	Lower	. Oligocene.
4. Khirthar	. . .	. Eocene.
5. Ranikot	. . .	. Lower Eocene.
6. Deccan trap, *Cardita beaumonti* beds[1] and sandstones .	.	. Passage beds between cretaceous and tertiary.
7. Limestone with *Hippurit* .	. .	. Cretaceous.

Representation of Sind groups to northward.

Of these various systems and groups, the Siwalik or Manchhar continues almost unaltered from Sind into the Western Punjab, both the upper and lower subdivisions being not only well represented, but easily distinguishable from each other, as far north as the Sulemán range was examined. The lower subdivision, however, is wanting near Sibi and Quetta. Of the Gáj group, on the other hand, no trace was detected north of Sind, the beds near Quetta and Sibi that were referred to that group by Mr. Griesbach[2] being, I think, certainly Siwalik, as will be shown subsequently. The oligocene limestone (lower Nari) was seen at one locality in the Bolán Pass, but is wanting throughout the rest of the country; the upper Nari sandstones, however, although not ol served in the Bolán, and absent on the Harnai route, and throughout the greater portion of the Bugti hills, re-appear to the eastward, and are found fairly represented throughout the eastern flank of the Sulemán range as far north as the examination was carried. Thus it will be seen that the change in the upper tertiary beds, in passing from the Khirthar range of Sind to the Sulemán of the Punjab, consists in the entire disappearance of the two marine subdivi-

[1] These and the underlying sandstones I have hitherto (*l. c.*) classed as cretaceous. The examination of the corals and echinoderms by Professor P. M. Duncan shows, however, that, despite some species with very marked cretaceous affinities, there is, on the whole, a preponderance of tertiary forms. The olive shales too, which form a considerable proportion of the subdivision, prove, further north, to be characteristic eocene beds, and there seems great reason to believe that the *Cardita beaumonti* beds, whatever their exact age may be, must be classed for stratigraphical reasons with the eocene rather than with the cretaceous system of Western India.

[2] Mem. G. S. I., Vol. XVIII., Pt. 1, p. 18.

sions, the lower Nari (oligocene) and the Gáj (miocene) of the first named hills.

Of the older tertiary beds the nummulitic group or Khirthar of Sind is everywhere well represented, but the Ranikot has not been detected again, and appears very possibly to be a local stage with a peculiar and rich fauna. The eocene beds of the Sulemán range have at the base a considerable thickness of hard brown sandstone.

Previous observers.

The geologists who have described portions of the area noticed are not numerous, and with but very few exceptions their attention was confined to the Bolán Pass and its neighbourhood. Only two papers of any importance—one by Captain Vicary, on the Bugti hills, the other by Mr. Ball, on a section across the Sulemán range—refer to other parts of the area traversed. It will be most convenient to notice first the geological descriptions of the Bolán Pass and its vicinity, including Quetta, by themselves, and then to pass in brief review the papers referring to the geology of other parts of the area.

Papers on Bolán Pass and neighbourhood.

Most of the travellers who visited Afghanistan before the first Afghan war passed at one time or another through the Bolán Pass, which then, as now, was the principal trade route between Sind and Afghanistan. Descriptions of the pass were given by Conolly, Masson, and others, but no details were mentioned of geological interest.

Griffiths, 1841.

In Dr. Griffiths' "Extracts from reports on subjects connected with Afghanistan," published in 1841,[1] he called attention to the peculiar forms of the valleys and plains of Afghanistan, and cited as examples some of those around Quetta. He especially noticed the slopes of gravel, or "glacis slopes" as he very appropriately called them, along the margins of the plains.

[1] J. A. S. B, Vol. X, p. 803.

He differed from Lord,[1] who attributed the drainage of the valleys around Cabul, supposed to have been originally lakes, to a great rush of water through the Khyber Pass. In Dr. Griffiths' "Private Journals," published in 1847, there are many notes,[2] chiefly botanical, on the observations made by their author in the Bolán Pass, but few, if any, of geological interest.

Griffiths, 1847.

In the Journal of the Royal Geographical Society for 1842[3] is an extract from a letter written by an officer in the Bengal Artillery and giving some notes on the Bolán Pass. These include a few details of the rocks; the coal near Ab-i-gúm (Mach) is especially mentioned, and its high dip graphically represented.

Anon., 1842.

The earliest detailed account of the geology of the Bolán Pass was published in 1846 by Captain T. Hutton, in his "Notes on the geology and mineralogy of Afghanistan."[4] After describing the sulphur mines of Bágh, he gave an account of the low hills on the road between Bágh and Dádar, noticed the presence of foliated gypsum, and referred the beds to the tertiary period, to which, when Hutton wrote, the nummulitics were not supposed to belong. He then described the rocks at the entrance to the Bolán as composed of alternating strata of sandstone, clay, and conglomerate. He recorded the appearance above Condye (Kohandiláni) of nummulitic limestone, and its identity with the rock seen at Sukkur on the Indus, and gave an account of the stony plain of Keirtah (Kirta), which he says is enclosed on the left (west) by strata of sand and clay and on the right (east) by nummulitic limestone. This is not quite the case; nummulitic limestone occurs on both sides, but there are some argillaceous and sandy beds underlying the limestone.

Hutton, 1846.

[1] J. A. S. B., Vol. VII, p. 521. Dr. Lord's paper entitled "Some account of the Koh-i-Damàn, the mining district of Ghorband and the pass of Hindu-Kush" is a valuable contribution to the geology of Afghanistan. It has been overlooked by Mr. Griesbach, and is not included in his list of papers on the geology.

[2] Pages 330-341.

[3] Vol. XII, p. 109.

[4] Calcutta Jour. Nat. Hist., Vol. VI, p. 562.

Near Ab-i-gúm, Captain Hutton found masses, not *in situ*, of indurated marly clay containing fresh-water shells, amongst which Mr. Benson recognised *Melania pyramis (M. tuberculata)*, *M. elegans* (*M. scabra*), and *Planorbis indicus* (*P. exustus)*, also *Unio*, *Cyrena* (*i.e.*, *Corbicula*) and *Paludina*. Captain Hutton could not tell precisely whence the fragments came, but thought they were washed down from some of the hills, and he remarked upon the occurrence of similar shells in Siwalik strata. These fossils do not appear to have been noticed by subsequent observers. No mollusca have yet been obtained from the Upper Siwalik beds of Sind or of the Western Punjab, whilst the fossiliferous Lower Siwaliks are not known to occur in the Bolán Pass. Perhaps, the marls with shells were of post-tertiary age.

The rocks of the upper part of the pass were equally well observed, but, misled apparently by the idea that the coal beds between Sir-i-Bolán and Ab-i-gúm must be of carboniferous age, Hutton supposed the cretaceous limestones around Dozán and along the borders of the Dasht-i-bedaolat to be mountain limestone, and the olive shales and coals of Mach to belong to the coal formation; whilst he thought he found specimens of oolite at Ab-i-gúm. The nummulitics were of course classed as cretaceous. On the other hand, he recognised the resemblance of the sandstones and conglomerates at the foot of the pass, and "opposite to the strata of shales near Sir-i-Bolán," to the Siwalik tertiary strata, and if, as I suspect, the conglomerate near Sir-i-Bolán is the same as that about Ab-i-gúm and around the Kirta plain, he was in all probability right in both cases.

The immense accumulations of rounded water-worn stones dispersed over such plains as that of Kirta were noticed. These accumulations could not, Hutton thought, have been formed in lakes, but must have been deposited in "deep waters...... in violent agitation," and he attributed them to a great rush of water[1] due to the elevation of the strata after the tertiary (*i.e.*, Siwalik) beds were deposited.

[1] A series of papers now being published in the Geological Magazine under the title "Traces of a great post-glacial flood" is devoted to an attempt to re-establish the theories held by Hutton's contemporaries.

Passing onwards from Quetta towards Pishin, he noticed the recurrence of tertiary clays and sandstones, and remarked on the presence in them of foliated gypsum, as near Dádar. Hence, quite correctly, he identified the Pishin and Dádar rocks. He also made some very acute observations on the form of the hills, attributing it to weathering (*i.e.*, subaërial action), and not to lacustrine denudation, despite the resemblance of the valley to a lake basin. This part of the paper reads as if it had been written thirty years later.

The next description to be noticed is by my friend Dr. H. Cook, who published a series of papers on the geology of Kalát (Khelat) and its neighbourhood. In one of these, entitled "Geological Report on a part of Beloochistan," published in 1859,[1] there is an account of the geological observations made on a journey through the Bolán Pass. It is unnecessary to recapitulate these, which are for the most part quite correct, at any length. In the hills between Mittri and Dádar conglomerate, sandstone, and clay with veins of gypsum, the whole covered by a thin layer of pebbles, were observed; then after a brief notice of a pass in the main range, 5 miles north of Dádar, the entrance of the Bolán Pass was described through clay, sandstone, and conglomerate. Dr. Cook appears to have looked upon the whole gorge above Kohandiláni as composed of the latter. The fact is that the nummulitic limestone in contact with the conglomerate is so nodular, that it is not easy, without looking at them closely, to distinguish the two, the conglomerate being composed of fragments derived from the limestone.[2]

Cook, 1859.

Dr. Cook noticed the clays and shales below the limestone on the road from Kohandiláni to Kirta, and gave a good description of the road from Kirta to Ab-i-gúm. He observed the conglomerate range

[1] Trans. Med. Phys. Soc., Bombay, No. 5, New Series, p. 105. The paper was printed in the absence of the author, and is full of misprints.

[2] Mr. Griesbach, Mem. G. S. I., Vol. XVIII, p. 30, says that passing through this limestone at night, he mistook it at first for conglomerate; and I, when riding up the pass, had gone some distance beyond the junction before I noticed that I had entered the limestone.

at the base of the hills west of the last named place, the coal at the halting place of Ab-i-gúm (probably that now called Mach, as it was said to be 6 miles from Sir-i-Bolán), the absence of nummulites in the limestones above Sir-i-Bolán, and the thin strata of yellow, red, and white limestones.

In his summary he distinguishes between the sandstones, conglomerates, and clays east of Dádar, and those at the bottom of the Bolán, as so many others have done. The fact is, I believe, that the beds belong to the same system and even to the same subdivision, Upper Siwalik, but the rocks east of Dádar are less disturbed. He did not recognise the pretertiary age of the limestones west of Sir-i-Bolán, although he noticed the absence of nummulites.

Hughes, 1877.

Mr. A. W. Hughes in a work called "Balochistan" (1877) has taken all the information he gives on the geology from Dr. Cook.[1] A few details on the geology of the Bolán Pass are derived from the same authority.[2]

Exhibition of Hippurites, 1879.

In 1879 I exhibited some specimens of *Hippurites* from Siahgai (or Siasgai), 70 miles east-north-east of Quetta, at a meeting of the Asiatic Society of Bengal.[3] These specimens, which were well preserved, were collected by Dr. Oldham, of the 1st Ghurka regiment, and were the first evidence brought forward of the occurrence of hippuritic limestone in Southern Afghanistan.

Geographical papers, 1880-81.

In various geographical papers published after the second Afghan campaign, and especially in those by Sir M. A. Biddulph,[4] Sir R. Temple,[5] and Captain T. H.

[1] Pages 11-14.

[2] Geology, and, I may add, zoology and botany are only incidentally mentioned in Mr. Hughes's works on Sind and Baluchistan, but his remarks are not always correct. For instance, he says (Balochistan, p. 14) that little or nothing appears to be known of the geological features of the mountains in Kaláti and Persian Makrán. It is true that very little is known, but still, as he quotes Major St. John as an authority for the geography, and must apparently have derived the details he quotes from the first volume of "Eastern Persian," he must have overlooked the few geological notes in the second volume.

[3] Proc. A. S. B., 1879, p. 202.

[4] Proc. R. G. S., 1880, p. 212.

[5] Ibid, 1880, p. 529.

Holdich,[1] the physical features of the Bolán Pass and the neighbourhood of Quetta are frequently noticed. These features are precisely those which attracted the attention of Hutton, Griffiths, Vicary, and others 30 years earlier; the wide alluvial plains with glacis-like slopes of gravel along their margins, and the long ridges of hills crossed by occasional clefts through which streams find their way to lower levels.

Griesbach, 1881.

By far the most important and complete geological description of the Bolán Pass and the neighbourhood of Quetta, the first indeed made by a professional geologist, is that by my colleague Mr. Griesbach,[2] published in 1881. He traversed the Bolán twice and spent some weeks at Quetta. The state of the country was unfavourable for geological surveying, and he was able to see but little beyond the immediate neighbourhood of the route itself. The systems and subdivisions identified by Mr. Griesbach in the region visited by him are the following (p. 9) :—

Recent .	. Alluvial and aërial.	
Post-pliocene	. Conglomerates, clays, &c.	
Pliocene .	. 1. Manchhars (Siwaliks).	
Miocene .	. 2. Gáj beds.	
Eocene .	. 3. Nummulitic limestone. 4. Ranikot group. 5. Alveolina limestone.	1. Nummulitic limestone. 2. Sandstones, shales, &c.
Cretaceous .	. 6. Deccan traps, &c. 7. Upper cretaceous limestones, shales, &c. 8. Hippuritic limestone and contemporaneous traps.	

With many of Mr. Griesbach's observations I fully agree, but there are a few points on which I have come to a different conclusion. A considerable portion of the route surveyed by him,—all, in fact, west of the Ghháziaband Pass, is beyond the area visited by myself. My opportunities for examining the Bolán Pass and the hills around Quetta, owing to the short period of time that I could devote to them, were less than Mr. Griesbach's, and I should hesitate to express opinions opposed to his,

[1] Proc. R. G. S., 1881, p. 65.

[2] Report on the Geology of the section between the Bolán Pass in Baluchistan and Girishk in Southern Afghanistan, Mem. G. S. I., Vol. XVIII, Pt. 1.

were it not that I have had much better opportunities of becoming acquainted with the rocks of Western India, and especially with the tertiary strata, than he has, and that I think in one or two cases he is mistaken in his interpretation of particular sections. On the relations of beds to each other and on questions of physical geology, Mr. Griesbach is, of course, equally entitled to express opinions with myself, and I can only give my reasons for not concurring with him. The principal points of difference between us are the following: I think (1) that the beds identified by him as Gáj are really Siwalik, and that the identification is founded on erroneous data; that (2) his lowest stage of the eocene system in the Bolán Pass and near Quetta, the *Alveolina* limestone, cannot be accepted as a definite subdivision; that (3) some of the beds classed by him as trappean or trappoid, and upper cretaceous, are not of volcanic origin nor composed of volcanic rocks, and that they are of eocene age; and (4) that he is mistaken in believing that certain upper cretaceous beds occur in the Takátu range near Quetta, and in representing them as thus occurring in fig. 5, p. 29. The above are all, I think, sufficiently important differences to require notice. A few minor points will be discussed in the descriptions of my observations in detail.

Principal points of difference between Mr. Griesbach and writer.

The observations on the geology, in consequence of which I am induced to differ from Mr. Griesbach, will be stated hereafter at greater length. To avoid recapitulation, I shall now only refer to the more important. I have numbered above the four questions that appear to me to require discussion, and shall deal with them in order, beginning with the supposed Gáj beds.

1. The low hills on the western side of Kachhi that are traversed by the old road to the Bolán Pass between Mittri and Dádar consist of clays, soft sandstones, and conglomeratic beds, and contain some gypsum. These beds are (quite correctly, I believe) identified by Mr. Griesbach with certain sandstones, conglomerates, and variously coloured clays, also containing gypsum, which occupy the northern extremity of the Chehiltan or Karaksar

Whether certain beds are Gáj or Siwalik.

range, immediately west of Quetta, and form the greater part of the next range to the westward, the Mashalak[1] range, traversed by the Gházíaband Pass. They are also largely developed in the Pishin valley, north of Quetta.

Rocks near Dádar.

These beds near Dádar and near Quetta are so positively stated[2] by Mr. Griesbach to belong to the Gáj group, that before I give my reason for dissenting, I think it is only fair to say that Mr. Griesbach has never, I believe, seen any Gáj beds, whereas these beds were originally distinguished by Mr. Fedden and myself, and I have examined the whole series of outcrops known between Cape Monze, west of Karáchi, and the northern extremity of Sind. I can see no resemblance between the typical Gáj strata and the beds near Dádar and Quetta; the characteristic rocks of the former are brown limestones, intercalated amongst soft sandy shales, brown to olive green in colour; the latter consist of pale brown sandstones, soft conglomerates or gravels, and clays of various colours. It is true that red and olive clays with white gypsum occur at the top of the Gáj beds at the river Gáj and for some distance north of it, but "these beds pass gradually into precisely similar strata belonging to the overlying Manchhar group,"[3] and there is no such striking similarity between the olive clays of the Upper Gáj and the white clays of the Dádar and Quetta hills, even although red beds are intercalated in both cases, as to show that the strata comprising them are identical. Red clays, of one tint or another, and gypsum are found in every tertiary subdivision of Western India, from Upper Siwalik to Ranikot.

[1] This is the name given in the survey map. Mr. Griesbach calls the range Dinar. It is not improbable that different names are used for different portions of the range.

[2] That this is the case, is, I think, shown by the following quotations from his report:—

"Near the boundary between Biluchistan and Afghanistan, I first noticed rocks, which I could at once identify with the Gáj group as described by Mr. Blanford in Sind," *l. c.* p. 18.

"The appearance and position of the rocks is so characteristic that there can be no doubt that it is the Gáj group of Sind," p. 20.

The grammar and construction of the last sentence are probably due to some press error but there cannot, I think, be any question as to the meaning.

[3] Mem. G. S. I., Vol. XVII, p. 54. See also p. 91.

But whilst I can see no resemblance between the miocene Gáj strata of Sind and the beds near Dádar and Quetta, the latter appear to be absolutely the same as the pliocene Siwalik or Manchhar rocks of their own immediate neighbourhood. Mr. Griesbach has, I think, quite correctly identified the rocks of the Nári gorge north of Sibi and those of Pir Choki, at the foot of the Bolán, with the Manchhars. Now the sandstones of the Nári and Bolán sections appear to me undistinguishable from those east of Dádar and those of Gháziaband; the conglomerates are similar, and contain the same pebbles, and the clays only differ in the paucity or absence of red and white beds in the Nári and Bolán sections. The presence of gypsum and its mode of occurrence were noticed by Mr. Griesbach himself [1] in the Nári gorge. This gypsum moreover, although its mere presence is unimportant, does, by its mode of occurrence, afford some evidence of connexion between the beds, for in all the localities mentioned, and in places on the western margin of the Bugti hills, the mineral occurs in thin plates, filling cracks that run across the bedding in various directions; and in the Western Bugti hills, where alone, of all the places named, both Upper and Lower Siwaliks occur, this form of gypsum is peculiar to the upper subdivision. The absence of any grey (pepper and salt) sandstones, and of conglomeratic beds containing clay and sandstone pellets, together with the occurrence of nummulitic limestone pebbles, proves, I think, that the beds east of Dádar and those of the Gháziaband Pass near Quetta are Upper and not Lower Siwaliks, and that they belong to the same subdivision as the strata of the Nári and lower Bolán sections.

Mr. Griesbach considers that the position and appearance of the Gháziaband rocks prove them to be the Gáj group. I have shown why I cannot coincide with this view of their appearance. As to their position, it is true that both overlie eocene beds,[2] but the Gáj group

[1] Page 15.

[2] Mr. Griesbach may also mean that Gáj beds come in immediately beneath the Manchhars, and the Dádar beds underlie the Manchhars or Siwaliks of Pir Choki. This last, as will

almost always rests conformably on the Nari (lower miocene or oligocene), whilst the Gháziaband beds rest unconformably on nummulitic strata (eocene). The position therefore is not identical, although taken alone it affords no evidence one way or the other.

It is evident, however, that one of Mr. Griesbach's chief reasons for identifying the beds of Gháziaband and Dádar with the Gáj of Sind, is the occurrence of gypsum in the former, and his belief that *gáj* is the Pushtu name for gypsum.[1] I suppose that he insists upon this Pushtú word under the impression that the Gáj beds were thus named in consequence of their containing gypsum. This is not the case; the term, as has been, I think, distinctly stated,[2] was derived from a river in Sind, and this river traverses a country where Pushtu is unknown. I have made enquiries from Europeans well acquainted with Baluchi and Sindhi, and also from natives, but all agree that the name of the river Gáj is of unknown signification. Moreover, so far as I could ascertain, *gáj* is not the Pushtu for gypsum, nor could I learn that any such word exists in Pushtu.[3]

The Pushtu name for gypsum.

be shown hereafter, is rather doubtful, but as the Siwalik beds are many thousand feet thick (there can scarcely be much less than 7,000 to 8,000 feet exposed in the Nári section), the Dádar beds might well underlie those of Pir Choki, where the whole thickness is not exposed, and yet belong to the Siwalik system.

[1] Thus he says (p. 19) of the Dádar beds: "The existence of numerous masses and irregular beds of gypsum (Pushtu: gáj) at once suggested the identification with Blanford's Gáj group. At page 21 and page 59 he repeats the statement that gáj is the Pushtu for gypsum.

[2] Rec. G. S. I., Vol. IX, p. 9. Mem. G. S. I., Vol. XVII, p. 53.—Manual of Geology of India, p. 463.

[3] Two words were given to me by different people as the Pushtu for gypsum. Mr. Ingle, the Assistant Political Agent at Quetta, made enquiries amongst the native employés, and was informed that the Pushtu word used was *askhár*. The head man of Mehtarzai village, close to the Gháziaband Pass, and to places whence the mineral is procured for building purposes, called it *záwé*. Both ignored the word *gáj*.

I am indebted to Sir O. B. St. John, who had noticed Mr. Griesbach's mistake, for the following very probable explanation. There is a Persian word *gach* (pronounced to rhyme with *such*), which means either gypsum or plaster made from burnt gypsum (plaster of Paris in fact). Such plaster is used very largely in Persia and Afghanistan instead of mortar, and the Pushtu builders, who have probably derived the art of building with plaster from the Persians, use the Persian term for that material. Mr. Griesbach must, I think, have confounded the two words *gach* and *gáj*.

Whether the "Alveolina limestone" forms a definite stage.

2. There is, I believe, neither in the Bolán Pass nor near Quetta, any definite stage or subdivision that can be called the *Alveolina* limestone at the base of the eocene. *Alveolinæ,* like nummulites, are found throughout the system, from top to bottom, in places. Thus at Spintangi, on the Harnai route, and also at Tang on the road from Quat-Mandai to Thal-Chotiali, there is a thick band of eocene limestone abounding in *Alveolinæ* and *Nummulites.* This band of limestone is near the top of the system, there being only 500 to 1,000 feet of shales overlying. Again, at a spot in the Bugti hills, at the western extremity of the Zen range, north-east of Sháhpur, *Alveolinæ* abound in the uppermost eocene bed together with *Nummulites.* There is, in this last case especially, no reason to suspect any removal of higher eocene beds by denudation, the overlying strata, Lower Siwalik, being to all appearance conformable. On the other hand both *Alveolinæ* and *Nummulites* are often found in beds at or near the base of the eocene. I did not myself notice *Alveolinæ* (although I found *Nummulites*) in the beds beneath the eocene (Mach) shales (Ranikot group of Griesbach) near Sir-i-Bolán, but this is of trifling importance; the distribution of these *Foraminifera* is far from uniform, and if two of us examined the same bed at places a few yards apart, one might easily find *Alveolinæ* and the other none. The point I wish to insist upon is, that to subdivide the eocene system, in descending sequence, into nummulitic limestone, Ranikot beds and *Alveolina* limestone is not correct so far as my knowledge extends, because the *Nummulites* are not confined to the upper subdivision nor the *Alveolinæ* to the lower, and because, so far as I have seen, there is no distinct band of limestone, whether characterised by the abundance of *Alveolina* or not, of sufficient importance to be distinguished as a primary subdivision or stage, either in the Bolán Pass or near Quetta, at the base of the eocene system. For

I have not entered into the question whether, if *gáj* really were the Pushtu name for gypsum, the coincidence would be a valid reason for classing the gypsiferous rocks near Quetta with the Gáj group of Sind, because that is a matter on which I think any geologist can judge for himself.

reasons to be given hereafter, I should prefer not to use the term Ranikot group for the beds of the Bolán, but this is of small importance, as I quite agree that the two may be of the same or nearly the same age.

Whether certain beds near Quetta are of cretaceous age and contain volcanic material.

3. The upper cretaceous beds near Quetta are thus classified by Mr. Griesbach (p. 34), in descending order :—

6. Passage beds: shales and limestones.
5. Liver-coloured shales and grits, trap.
4. Hard dark limestone.
3. Red, white and variegated shales and argillaceous limestones.
2. Hard, grey limestone; *Inoceramus*, corals.
1. Hippuritic limestone.

A description of the section west of Kari (at the northern end of the Chehiltan range), from which the above classification is deduced, is given on the next page (35), and two figures of sections through part of the range on page 37. Some details of one of these sections from my observations will be found in a subsequent page of the present Memoir (in Chapter V).

I believe that the two uppermost subdivisions, 5 and 6, are eocene. There cannot, I think, be any doubt about my identification of the beds in Mr. Griesbach's section. I recognised them easily from the figures and description. The division marked 5 is, however, very much thicker than it is represented in the section. I do not quite understand the shales being described as "liver-coloured."[1] All I saw were pale greenish-grey or olive, the common colour of the eocene shales throughout the system from top to bottom. These shales of the Chehiltan range seemed to me to be clearly the same as those seen north of Quetta, at the base of Takátu mountain,[2] where bands of limestone abounding in nummulites and *Alveolina* are intercalated with them. I think too there can be no

[1] By "liver-coloured" I understand a reddish-brown approaching chestnut. The term is commonly applied in this sense to dogs, *e. g.* a "liver-coloured" pointer.
[2] They were considered identical by Mr. Griesbach also.

reasonable doubt that the shales with coal classed by both of us as eocene at Mach, near Sir-i-Bolán, are the same strata. If this is the case, it is evident that both 5 of the section near Quetta and the overlying "passage beds" 6 must be eocene.

With regard to the presence of trap in No. 5, I could find none either at the section west of Quetta or to the northward. At the former locality trap is not absolutely said to occur; Mr. Griesbach's words (page 35) are: "the shales are evidently made up of trappean materials." At the base of Takátu the same bed is called "trappoid" (page 36), and in the figure 5, page 29, it is entitled "trap band." In neither locality could I find any volcanic rock or any evidence of detritus derived from a volcanic formation, and I carefully examined some coarse grits and conglomeratic beds at both places. The shales at both localities, and in many others where the same beds are found, weather at the surface into a powdery mass, which has an unquestionable resemblance to decomposed basalt,[1] but they are, I believe, a form of marine sediment coloured by some silicate of iron protoxide.

Trap of Bolan.

The trap in the Bolán I did not myself see. Mr. Griesbach looks upon it as representing the shales No. 5 near Quetta, but, from the description that he gives, the horizon at the Bolán must, I think, be lower than that of the Quetta shales. If I understand his description at page 39 correctly, the shales with which he says that he found the trap associated between Darwáza and Dozán can only be the limestone shales so well seen at Dozán; and these are, I think, clearly the same as No. 3 of Mr. Griesbach's section near Quetta, not the supposed trap bed No. 5.

It is not improbable that the supposed existence of a distinct band of *Alveolina* limestone at the base of the eocene has misled Mr. Griesbach as to the position of the beds west of Quetta. At page 35, he writes· "a small stream......has exposed a good section from the lower eocene

[1] The Talchirs of Central India and Western Bengal are of nearly the same colour, and I have known them in two separate instances to be mistaken for trap by geologists of experience.

Alveolina limestone into the *Inoceramus* limestone," and he commences his description of the section thus: "*overlying beds, Alveolina limestone.*" It is true that in the figured section, page 37, no *Alveolina* limestone is shown. If, however, as his remarks imply, he found limestone with *Alveolina*, his mistake, or what I consider his mistake, in classing the shales and limestones No. 6, and shales and grits No. 5, as cretaceous instead of eocene, is explained by his supposing that there is a definite band of *Alveolina* limestone at the base of the eocene.

Whether cretaceous beds occur at base of Takátu.

4. Takátu hill north of Quetta, so far as I could ascertain, is entirely composed of eocene rocks; the upper portion of limestone with nummulites, and the lower of shales with which bands of nummulitic limestone are intercalated. I spent a day in examining the base of the hill between the road to Pishin and that to the Harnai Pass, and I marched through the latter, so that I saw the whole of the south-eastern and southern side of the hill. I was unable to find either the "variegated flags" or "*Ostrea* limestone" represented on figure 5, page 29, of Griesbach's report. If they occur at all[1] and I have very little doubt they do, they probably crop out in the hills south-east of the Harnai road, along the south-eastern side of the ridge called Nar on the Topographical Survey map. The "trap bandh" of Mr. Griesbach's section is, as already stated, the upper part of the eocene shales, and appears to me not volcanic. One result is that the boundary between cretaceous and eocene rocks south-east of Takátu, if my views are correct, must be drawn about 5 miles further to the south-east than it is represented in Mr. Griesbach's map.

Additions made by Mr. Griesbach to geological information.

In concluding this criticism, and to prevent its being supposed that I have only objections to urge to Mr. Griesbach's work, it is right to point out the important additions made to our previous knowledge by his observations. The wide

[1] To account for my not having seen them, I must plead that my visit to Quetta was not for the purpose of mapping the country, and that my time was very limited, whilst, misled by Mr. Griesbach's accounts, I lost the only day I could spare in hunting for the passage beds at the place where he represents them as occurring along the base of Takátu.

extent occupied by the cretaceous limestones in Southern Afghanistan, the remarkable association of granitic rocks with these limestones, and the similarity of this association to occurrences of the same kind amongst contemporaneous strata in Hungary are most valuable geological observations. The resemblance of the sandy and shaly type of eocene strata to the "flysch" of Central Europe is very interesting. And although I have been obliged to dissent from the interpretation of certain sections represented in Mr. Griesbach's figures, it is only fair to say that many of his plates are not only correct, but good representations of the geology. I may cite as instances Plates I and IV, it being, however, understood that I do not accept the names given to some of the strata in the latter case.

Papers on Bugti Hills.

I am acquainted with only a single description of the rocks seen in the Bugti hills. Few geological papers on India have, however, become more widely known than Captain Vicary's "Geological Report on a portion of the Beloochistan hills," originally published in the "Quarterly Journal of the Geological Society of London,"[1] thence copied into the "Calcutta Journal of Natural History,"[2] and again reprinted, som years later, by Dr. Carter in the "Geological papers on Western India."[3] A summary of the paper and a copy of the section were also given by D'Archiac and Haime in the "Animaux fossiles du groupe Nummulitique de l'Inde."[4]

Vicary, 1846.

The country traversed and described by Captain Vicary extends from the desert plain north of Jacobabad (a town that had no existence in 1846, when Captain Vicary's report was published) to the hills near Dera (Deyrah) on the confines between Bugti and Mari (Murray) territory. Seven ranges parallel to each other are enumerated and represented on the section.[5] These are the east and west ridges of the

[1] Vol. II, 1846, p. 260.
[2] Vol. VII, p. 385.
[3] Page 521.
[4] Pages 169-171.
[5] The route followed by Captain Vicary is evidently that from Jacobabad to Dera by Shahpúr given in Hughes' "Balochistan," page 277.

Bugti country, and most of those mentioned by Captain Vicary are easily traceable. The southernmost, consisting of sandstone, near the desert, is evidently that near Uch, Goránári, &c., formed by low rises of Siwalik strata. The second, also of sandstone, and traversed by the "Jullock Pass"[1] is the well marked range of Siwalik sandstones, marls, &c., that extends along the southern side of the nummulitic anticlinal known as Zen or Zin, which itself is the third range. The fourth is, I think, a part of the same range as the third, Captain Vicary, who drew the section from memory, having forgotten or misunderstood a slight curve in the strike east of Kúmbi (Coombie). The fifth range, the conglomerate of the Dera(Deyrah) valley, is the Upper Siwalik conglomerate ridge along the north side. The sixth range or Traki (Trukkee) is the nummulitic limestone range north of the Dera valley, and the next ridge to the northward, that called "Murray hills," is doubtless the range north of Traki, crossed by the road to Káhan, in the Mari country, at the Naffusak Pass.

Most of Vicary's observations are good, except that he appears to have repeatedly mistaken the concretionary structure so often seen in ferruginous clays, marls, and sands for an effect of calcination, and to have been induced to suppose that the richly coloured beds of the Lower Siwaliks afford evidence of volcanic action (pp. 262, 265). He also thought he saw the effects of volcanic agencies at Uch (Ooch) amongst Upper Siwalik beds, and at Duzd Kushtak (Doza Khooshtie) in nummulitic limestone. So far as the localities have been examined, there appears no reason for supposing that the phenomena observed have any connection with igneous action.

The remarkable clefts serving for drainage, in the surface of the nummulitic limestone ranges, were not likely to escape the notice of so acute an observer as Vicary, who attributed them entirely to fissures produced by the upheaval of the limestone. Some notes on these clefts and gorges will be found in the next chapter on Physiography, where a different view is taken of the manner in which they originated.

[1] Unless this is the Lalli Pass between Zuráni and Zen-ka-Kumb, I cannot recognise it.

Amongst the most valuable of Vicary's discoveries was one of which the importance was scarcely suspected until the examination of the Sind Manchhar (Siwalik) beds. This was the occurrence of mammalian and reptilian bones and of mollusca, in the beds above the nummulitic limestone, on both sides of the range of hills south of Dera. The specimens obtained by Vicary appear never to have been examined, but when it was found that the fragmentary mammalian remains found in the Lower Manchhar beds of Sind belonged apparently to an earlier age than the typical Siwalik fauna, it was naturally suspected that the bones, said by Vicary to be found in such abundance in the Bugti hills, would also be the remains of the more ancient epoch. This has proved to be the case. The shells referred by Vicary to *Paludina* and *Cardium* have also been found again; the first genus was correctly identified, but the supposed *Cardium* proves to be a curious form of *Unio*, very like a *Cardium* in form and with strong radiating ribs. As will be shown in the sequel, these mollusca are of peculiar interest, and their association with the mammalian bones has served to show more clearly than ever the difference in age between the Lower Manchhar or Lower Siwalik beds and the typical fossiliferous Upper and Middle Siwaliks at the base of the Himalayas.

Papers on Sulemán range.

Vigne, 1840.

With the exception of Mr. Ball's paper, as already mentioned, the published contributions to our knowledge of the hills along the western frontier of the Deraját are excessively meagre. Vigne traversed the Gomal Pass in the northern part of the province, and recorded the occurrence of mountain limestone[1] and of ammonites.[2] It is possible that his supposed mountain limestone, like Fleming's, was really of later age, but it may have been carboniferous, for it is evident that a change occurs in the rocks, and in the character of the range itself, north of the Takht-i-Sulemán.

In a letter from Dr. Fleming[3] to Sir R. I. Murchison, "on the

[1] Personal narrative of a visit to Ghazni, Kabul, and Afghanistan, 1840, page 80.
[2] *Ibid*, p. 81.
[3] Q. J. G. S., Vol. IX, p. 346.

Geology of part of the Sulemán Range," published in 1853, there are a few notes on the rocks forming the outer ranges near the plain of the Derajât. The "belt of boulder deposit" separating the "alluvial desert tract" from the "Sulemán ranges" is noticed, and also the derivation of the boulders from the rocks of the hills. The conglomerates forming the outer range are said to be identical with those of the Siwalik strata in the Salt Range, and the underlying sandstones are referred to the same system.

Fleming, 1853.

Dr. Fleming went about 3 miles up the Sunghur (Sangarh) Pass and found nummulitic limestone beneath the Siwalik sandstones, &c. The beds dip east, and he suggested that the main range forms the reverse slope of an anticlinal. It proves on examination to be a second anticlinal, the nummulitic limestones seen by Dr. Fleming forming the axis of the eastern convexity, and a synclinal, occupied by higher tertiaries (Siwalik, &c.), intervening between the two.

One remark of Dr. Fleming's proves to have been a mistake. He states that he found boulders of *Productus* limestone (the carboniferous limestone of the Salt Range) in several water-courses, and in a note at the end of the paper, he is said to have found "boulders of white quartzite and *Productus* limestone at the mouth of the Vadur or Vidore (misprinted Vidone) Pass opposite Dera Ghâzi Khân. The occurrence of carboniferous limestone in the Sulemán range was consequently mentioned in the "Manual of the Geology of India"[1] on Dr. Fleming's authority. It is evident, after the examination of the range, that the occurrence of carboniferous limestone is extremely improbable, no trace of any beds older than cretaceous having been detected in the Vadur and Sangarh Passes, and there can be very little doubt that the limestone supposed by Dr. Fleming to be *Productus* limestone was really the dark cretaceous limestone of the Sulemán, and that his white quartzite was the hard upper cretaceous sandstone.

Erroneous account of occurrence of *Productus* limestone.

[1] Pages 486-491.

Lieutenant H. G. Raverty, in "An account of the mountain district forming the western boundary of the Lower Deráját, commonly called Roh, with notices of the tribes inhabiting it,"[1] gives some interesting remarks on the physical geography of the ranges.

Raverty, 1859.

The two papers next to be noticed refer to a portion of the Sulemán range farther north than the area examined by me, but they are very interesting, because they show that a complete change takes place in the geology near Bannú, and that metamorphic rocks, and perhaps some palæozoic or lower mesozoic beds, appear from beneath the tertiaries. In the Proceedings of the Asiatic Society of Bengal[2] for July, 1860, there are printed some extracts from letters written to Dr. T. Oldham by Dr. J. L. Stewart, who accompanied the 14th Bengal Infantry on the expedition led by Brigadier (afterwards Sir N.) Chamberlain into the Waziri country. The route followed led north-west from Tak (Táuk) to Kanigoram, thence for some distance northward. Dr. Stewart records having passed over soft sandstones and conglomerates (Siwalik) and then over calcareous strata, red and greenish disintegrating beds, sandstone, &c. (nummulitic), which extended to beyond the Barrara Pass. Farther to the westward, near Kanigoram, slaty beds, contorted and wavy in places, were found, with thin sandstones. These may either be eocene beds somewhat disturbed and having the flysch-like aspect, or more ancient deposits. Vast quantities of granitic (probably gneissic) detritus were observed, showing that metamorphic rocks probably occur at no great distance.

Stewart, 1860.

Dr. Verchere, who accompanied the same expedition, gave a somewhat more systematic account of the country in his paper "On the Geology of Kashmir, the Western Himalaya, and Afghan Mountains."[3] He says that the expedition traversed the plateau of Rusmuk at an elevation of 7,000 feet, and that the main range to the westward is composed of "volcanic, trappean,

Verchere, 1867.

[1] J. A. S. B., Vol. XXVI, p. 177.
[2] J. A. S. B., Vol. XXIX, p. 314.
[3] J. A. S. B., Vol. XXXVI, 1867, Pt. 2, p. 18.

and metamorphic rocks," of which pebbles are brought down by the torrents. The lower hills are said to consist of miocene (Siwalik, probably pliocene) sandstone and conglomerate, resting upon "nummulitic limestone, slate and shale," and beneath the latter flesh-coloured limestone, supposed to be old coral reefs, and referred with some doubt to the oolitic period. At one spot the supposed coral reef limestone was found resting on red marls and gypsum, containing quartz crystals with pyramidal terminations at both ends, and the same crystals are said to be found in the gypsum associated with rock salt and red marl at Mári and Kálábágh where the Salt Range crosses the Indus.

In the general section G[1] attached to Dr. Verchere's paper, miocene (*i.e.*, Siwalik), nummulitic, jurassic and "saliferien"[2] beds are shown to be repeated several times in the hills west of Bannú, but in so peculiar and irregular a manner as to render it probable that the section cannot have been clearly understood.

Ball, 1874.

My colleague Mr. Ball visited a reported coal locality in the Luni Pathán country, west of the Solemán range, in company with Captain (now Sir R.) Sandeman, and described the geology seen on the route across the range in 1874.[3] The paper was illustrated by a geological map and section, which not only gave a good idea of the geology, but added greatly to our knowledge, for no geologist had ever traversed the Solemán range before. Mr. Ball's route ran nearly due west from Dera Ghází Khán past Sakhi Sarwar, and he ascended the range by the Siri Pass.

The beds traversed were classified as recent, pliocene, miocene, and eocene. The strata referred with some doubt to pliocene were the conglomerates at the top of the Siwalik system, and there is now no doubt that the age was rightly assigned. The appearance, at the western

[1] J. A. S. B., Vol. XXXV, Pt. 2.

[2] Mr. Wynne, Mem. G. S. I., Vol. XVII, p. 213, shows that some of the beds west of the Indus, referred by Dr. Verchere to his "saliferien," are jurassic. It is impossible to say whether this is the case in the Waziri country. The peculiar character of the rocks in this country north of the Gomal Pass render Vigne's note on the beds seen in the pass very interesting.

[3] Rec. G. S. I., Vol. VII, p. 145.

extremity of the Siri Pass, of marked unconformity between the conglomerates and the lower members of the Siwalik system is probably, in great measure at all events, deceptive, and due to an abrupt change of dip, but at the same time it is so precisely like an unconformable junction that any one who, like Mr. Ball, only traversed the pass, and did not trace the relations between the beds to the northward and southward, would almost necessarily conclude that the conglomerates had been deposited against the inclined beds of sandstone, clay, &c. The subdivision of the strata below the conglomerates was also impossible to any one merely traversing them. The beds classed as miocene by Mr. Ball are partly, in all probability, of that age, partly newer. His belief, that not only the nummulitic limestone, but also the underlying shales and sandstone, amongst which some thin beds of coal occur, are of eocene age, is entirely in accordance with the observations since made on similar beds elsewhere throughout the western frontier of India.

The repetition of the eocene rocks by alternating anticlinals and synclinals west of the Sulemán is precisely similar to the behaviour of the same beds in the country traversed by myself further south, and appears to indicate that a very large area is covered by these strata, whilst Mr. Ball's section adds another instance of the inconstancy in development of the nummulitic limestone, which he found 1,000 to 2,000 feet thick in the hill ranges to the west of the Sulemán, whilst to the eastward only a few feet occur. The white sandstones noticed by Mr. Ball at Han-ki-der and on the peak of Ek Bhai, both situated at the crest of the Sulemán, are probably cretaceous, as will be shown hereafter. The eocene coal, though of good quality, proved to occur in seams too thin to be worked with advantage. Some additional details will be found below as to the sulphur of the Bozdár country.

Temple, 1879.

The last two papers to be mentioned refer to a tract which, like the Waziri country described by Drs. Stewart and Verchere, is, with the exception of one pass, not included in the area recently examined by myself. These papers are by Lieutenant R. C. Temple, and give an account of the country north of the

Harnai Pass, and of the Mari country, traversed by the second column of the Thal-Chotiali Field-Force between Pishin, north of Quetta, and the Deraját close to Harrand. One of these papers was published in England;[1] the other, entitled "Notes on the formation of the country passed through by the 2nd column Thal-Chotiali Field Force," appeared in India.[2] In the first the geological formations noticed are briefly alluded to and a note is added on the specimens collected, which were examined in the Geological Survey Office, Calcutta.[3] The fossil shells obtained were tertiary, and specimens of syenite, diorite, and earthy amygdaloid occurred, besides sedimentary rocks.

The second paper contains numerous geological details, but the majority of them are either petrological, or else merely record the occurrence of fossils, without specifying what the fossils are. Some doubt must exist as to the accuracy of the rock nomenclature, for the only portion of the route known to me, the Cháchar Pass, is said to consist of "a series of valleys and mountain ranges of more or less breadth, all of limestones, soft and hard, and of all colours." I found very little limestone in the Cháchar Pass, nearly all the rocks are sandstones, shales, and clays. It is therefore a question whether the schists and gneiss said to occur elsewhere on the route are correctly named. So far as the specimens afford information, it is probable that the ground traversed is principally composed of eocene strata, whilst the syenite, diorite, and other plutonic rocks may very probably have been associated with hippuritic limestone, which has been shown by Dr. Oldham's specimens, already noticed, to occur near Mount Siasgai on the route in question, and which probably extends for some distance. The association of syenite and of basalt with hippuritic limestone west of Quetta has been recorded by Griesbach, and I found a basaltic formation intercalated in the cretaceous beds of Kach and Amadun, about 40 miles west of Siasgai.

[1] Jour. R. G. S., 1879, p. 190.

[2] J. A. S. B., Vol. XLVIII, 1879, Pt. 2, p. 103.

[3] I recollect seeing these specimens in Calcutta. They were such as are frequently collected by travellers, and although they afforded some information as to the prevalent rocks, they were insufficient to furnish more than a vague idea of the geology.

Lieutenant Temple in both papers has noticed the remarkable slope of gravel on the margins of the plains, and attributes it, rightly I believe, to the disintegration of the hill rocks, and to fragments being washed down the slopes.

CHAPTER II.

PHYSIOGRAPHY.

General curve of hill ranges.

As may be seen by a glance at the map, the hills beyond the British frontier from the north-western extremity of Sind to Dera Ghâzi Khân are arranged in a very deep sigmoid curve. From the northern extremity of the Khirthar range west of Shikárpúr to the mouth of the Bolán (an area that, as already mentioned, has not been surveyed geologically), the general direction is north and south, but north of Dádar, at the entrance of the Bolán Pass, there is a change, and the general strike of the rocks, to which the ranges of hills are parallel, north of the Kachhi or plain around Sibi, Dádar, Gandáva, &c., is nearly north-west—south-east varying to west-north-west—east-south-east. This general direction prevails to the north-west as far as the neighbourhood of Quetta, and to the eastward far into the Mari and Bugti hills. The change in strike, so far as the imperfect observations hitherto made show, does not seem to be attended by any great amount of disturbance, the rocks in the Bolán, and especially the softer beds, are somewhat contorted, and the dips are naturally irregular and variable, but the shales are soft and present no approach to the induration that appears in the same beds to the west of Quetta.

Ranges west and north of Kachhi.

Bugti Hills.

Passing eastward into the Bugti hills the strike becomes east and west, and in the southern part of the hills, north of Jacobabad, the dips are very low, and indicate a passage to the conditions prevailing in the almost undisturbed eocene beds seen further south on the Indus around Sukkur and Rohri. Further

east, at the south-western extremity of the Punjáb, the east and west ranges of the Bugti hills curve round, and the Sulemán range runs, first north-by-east, then due north, parallel to the Indus river, along the western frontier of the Deraját. Some hardening of the shales and sandstones is seen about the place where the change in direction takes place.

Sulemán range.

The ranges near the Bolán Pass are somewhat irregular in direction and structure, and so are some of those around Quetta. Two of the latter, Takátu and Zarghún, both composed of nummulitic limestone, rise to a height of more than 11,000 feet above the sea. Many of the ranges of the Mari and Bugti hills, and some of those near the Harnai route, are simple anticlinals of nummulitic limestone, like the northern and southern extremities of the Khirthar (but not the greater part of that range), and several of the ridges in Southern Sind. The range running from north-west to south-east, north of the Harnai route, from the Chappar rift to beyond Harnai, appears to be one of these anticlinals, and it rises to an elevation, as recorded on the Topographical Survey map, of 11,400 feet north of Sháhrág. The ridges of the Bugti hills are lower. The main range of the Sulemán, as far north as it was examined, is an anticlinal of lower eocene and cretaceous rocks; it rises to an elevation of over 5,000 feet close to its southern extremity, and to a somewhat greater altitude farther north; two peaks, Ek Bhai and Saronk, to the westward of Dera Gházi Khán, being marked on the map as 7,400 and 7,600 feet high. Along the eastern side of the Sulemán are a number of low ridges, more or less continuous, parallel to each other and to the main range, and formed by the outcrop of the harder bands occurring in the eocene and newer tertiary beds. In this respect there is much similarity between the Sulemán and the Khirthar, but, as has already been shown, there are important differences in the tertiary subdivisions represented, and the Sulemán itself is composed of beds lower in position than those found in the Khirthar. The ranges of hills in the country west of the Sulemán appear in many cases to be anticlinal ridges.

Geological structure of ranges.

Between the different ranges of hills there are broad valleys and plains at a considerable elevation above the sea, an elevation that increases with the distance from the foot of the hills up to nearly 6,000 feet around Quetta, and 4,000 to 5,000 feet west of the Sulemán. The valleys and plains present the characteristic appearance of the central Asiatic plateaus; they are bordered by similar slopes of detritus derived from the hills, and they expand in places into open deserts, the surface of which is composed of fine soil, sometimes sandy, and due most probably to subaërial accumulation.[1] Owing to the paucity of the rainfall, both hills and plains are, as a rule, very sterile.

Valleys and plains.

The streams are very small and unimportant in themselves, but they possess a curious geological interest from the circumstance that their course is frequently at right angles to the hill ranges, and that many of them traverse gorges cut through anticlinal ridges. Two instances may be especially noted, the "Chappar rift," as it is called, on the Harnai route, and the gorge by which the Kaha traverses the Sulemán west of Harrand. In the first case, the stream draining all the valleys around Kach and Kawás, north-east of Quetta, cuts its way, just below a military encampment known as Mángi, through the anticlinal range of nummulitic limestone that, as already mentioned, rises to an elevation of more than 11,000 feet north of Sháhrág but is comparatively of small size at the Chappar rift. So narrow is the entrance of the gorge from the north that no passage can be seen; it appears as if the stream were entering the side of the hill. The gorge is about 2 miles long, and the sides are several hundred feet high at least.

Streams.

Gorges or clefts.

Chappar rift.

[1] For a description of similar plains in Persia, see Q. J. G. S., Vol. XXIX, p. 493 Eastern Persia, II, pp. 450, 465; and Proc. R. G. S., 1881, p. 79; also Tietze, Jahrb. k.k. Geol. Reichsaust., Vol. XXVII, 1877, p. 341.

The Afghan plains have been described and their physical features discussed by Lord, J. A. S. B., Vol. VII, p. 521; Griffith, J. A. S. B., Vol. X, p. 308; Hutton, Calc. Journ. Nat. His., Vol. VI, p. 562; and Griesbach, Mem. G. S. I., Vol. XVIII, pp. 10, &c.

The Kaha channel is even more remarkable, for not only is it of great depth, certainly more than 3,000 feet, but it is cut through excessively hard sandstone for a considerable portion of the way.[1] Through it the drainage of a very large tract of country west of the Sulemán range finds an outlet, and the quantity of water brought down after heavy rain must be very great. At the same time, it appears remarkable that the stream should traverse the highest range in the country, instead of making its way across lower ground to the southward, especially as that lower ground is composed, for a considerable depth at all events, of much softer rocks than those cut through in the Sulemán range.

Kaha gorge.

These two examples suffice to illustrate a phenomenon which is no novelty to geologists, and especially to geologists in India. Something similar, but on a gigantic scale, occurs in the Himalayas, and has been explained by Mr. Medlicott,[2] whilst Mr. Wynne has called attention to the peculiar manner in which rivers traverse the Salt-range of the Northern Punjab.[3] Other instances might easily be quoted, and in fact the occurrence in one form or another is common. It requires notice, however, because the clefts formed in the nummulitic limestone are so remarkable that no observant traveller can fail to be struck by them, and because the usual explanation, that such clefts are caused by dislocation,[4] or that they are cracks and fissures in the rocks, produced during the elevation of the ranges[5], does not appear to be in accordance with the evidence.

Popular explanation of clefts.

[1] A section of the beds is given in a subsequent part of this report.

[2] Manual of the Geology of India, p. 675.

[3] Mem. G. S. I., Vol. XIV, p. 46, and Vol. XVII, p. 11 (221).

[4] This apparently is my colleague Mr. Griesbach's view (*l.c.* p. 4), as he writes: "Dislocations, mostly vertical to the strike of the ranges have prepared the course (in the first instance) for rivers, as for example the Bolán, the Nári, &c." I can only say that I saw no evidence of dislocation in either of the cases quoted, and, so far as my observation has extended, it is a very rare exception, at all events in Western India, for a river gorge to correspond to a line of fracture in the rocks.

[5] Thus in Sir R. Temple's paper entitled "The highway from the Indus to Candahar," Proc. R. G. S., 1880, p. 540, he says: "From some volcanic forces in geological periods, there have been great chasms and rents formed in this wall" (the mountains of the frontier).

In support of the fissure theory, it is urged that the salient angles on one side of such clefts correspond to re-entering angles on the other, and that this shows that the two sides were formerly in contact.[1] But running water commonly cuts a more or less zig-zag channel, and as the sides of the ravine are denuded by the action of rain, the angles originally formed by the stream, although modified, are not obliterated. Either the whole surface of the slope is removed uniformly, or there is a tendency to exaggerate the salient and re-entering angles, because the latter form channels down which the water runs to the main stream during rain, and are consequently deepened by erosion, whilst the former escape abrasion.

Proof that popular explanation is incorrect.

The crucial test is the production of direct evidence that there has been dislocation (*i.e.*, faulting) along the line of the cleft, or that there has been an open fissure. This should be extremely easy, for the rock forming the channel of the stream is generally exposed every here and there. If there be a fault, it could scarcely escape detection, for the beds on opposite sides of the ravine would not correspond. If there has been an open crack or fissure,[2] it must originally have extended to a great depth, far below the present river channel, and must have been filled by fragments before the stream could pass over at its present level. The stream would, in such a case, run over a mass of re-cemented detritus. But it will generally be found that, beneath the loose pebbles, sand, &c., the bed of the stream consists of solid rock, and that where, as is sometimes the case, a calcareous conglomerate is found, this is a superficial deposit, and not a mass filling a deep fissure.

In all the cases where streams cut their way from side to side of a ridge,

"Rivers rise in the plateau which pass through these rents and chasms into the lower valleys."

[1] Vicary, Q. J. G. S., Vol. II, p. 268. I have more than once heard this argument used by other observers.

[2] It should also be remarked that open cracks or fissures, if any such are formed during the process by which rocks assume an anticlinal curve (it is possible that, owing to the pressure, no fissures form), would be parallel to the strike of the beds and to the axes of the anticlinals, and not transverse, as in all cases here noticed.

many other streams cut ravines and gorges, precisely similar in character, but of very inferior depth, from one side only of the water-parting at the crest of the ridge to the valley or plain on the same side. There can be no doubt that the smaller clefts are cut by water, and all that is necessary in order to account for the origin of the great transverse gorges by the same agency is an explanation of the way in which the larger streams began to cut their way through the hills.

All clefts due to erosion alone.

This explanation is that probably the stream once ran at a much greater elevation relatively to the position of the hard rock (nummulitic limestone at the Chappar rift; eocene and cretaceous sandstones and limestones in the Kaha gorge), and that this stream followed nearly the same course as now, but at a higher level and through softer beds. As the latter were gradually denuded away and the hard anticlinal exposed, the stream cut its way through the latter. But the hard rocks resisted the ordinary denudation of the atmosphere and rainwash, whilst the overlying soft clays and sands were carried away until the hard anticlinal remained exposed, just as a skeleton is left when the soft integuments are removed by maceration; the stream alone, by its greater power of erosion, having cut its channel to the depth required for the drainage of the country.

Probable explanation of difficulties in the case of transverse clefts.

It is also probable that the stream, in all the cases mentioned (it certainly is the case sometimes), is older than the disturbance to which the anticlinal is due, and the formation of the latter was so slow that the stream cut its channel deeper *pari passu* with the elevation. In both cases the channel is due to the same cause, the erosion of the stream now running through it.

Valleys probably older than disturbance.

In the neighbourhood of the Chappar rift, there is some further evidence that the course of the streams is of greater antiquity than the disturbance of the strata. The tract of country north of the Kachhi, as already mentioned, consists of ranges of hills having a general west-north-west—east-south-east direction, and these hills, composed partly of anticlinals, partly of scarps, of hard beds, are separated from each other by

broad valleys, often of so great extent as to assume the character of long plains rather than valleys, with the same general direction as the ridges, and corresponding to the outcrops of the softer strata. Had the form of the country been what it now is when the main drainage lines were traced, it is reasonable to believe that all the streams would run along these valleys, whereas the main drainage is across them; each stream, after coinciding with the plain in direction for a few miles, cutting its way through the next ridge to the southward.[1] It is difficult to account for this peculiarity, unless we suppose that the general direction of the streams is of greater antiquity than the disturbance of the rocks and the formation of the present ridges and valleys by denudation.[2]

Natural bridge at Sangsila.

The curious natural bridge at Sangsila in the Bugti hills, of which a figure is given in the frontispiece, is a very interesting example of stream action. A few details concerning this arch of rock will be given on a subsequent page with other notes on the geology of the neighbourhood.

CHAPTER III.

GEOLOGICAL SYSTEMS AND THEIR SUBDIVISIONS.

Area mainly tertiary.

Throughout the area traversed no beds of older age than cretaceous were observed. The greater portion of the country by far is covered with tertiary deposits, through

[1] This is not so conspicuous on the accompanying map as on the ground. The same phenomenon is seen to the westward in Makrán, north of Gwádar. The valleys or plains form a series of terraces, each in turn rising above that to the southward, and separated from it by a range of hills. The streams run across the terraces, not along them. See "Eastern Persia," Vol. II, p. 450, &c.

[2] Since this chapter was written I have received from Dr. Emil Tietze*, a very important memoir on the formation of transverse valleys. If I understand Dr. Tietze rightly, his views are precisely the same as those above advocated. It is scarcely necessary for me to add that there is a very large amount of literature extant on the subject of transverse valleys, chiefly by continental writers. The theory that transverse valleys are as a rule due to fracture or dislocation has, I believe, been practically extinct amongst the best English geologists for about 30 years. A very good account of the prevalent ideas amongst English geologists may be found in Geikie's Text book of Geology, pp. 371—379.

* Einige Bemerkungen uber die Bildung von Querthalern. Jahrb. k.k. Geol. Reichsanst., Vol. XXXII, pp. 685, 768 (1882).

which, as will be seen by a glance at the map, the cretaceous rocks protrude, within the country examined, only in the neighbourhood of Quetta to the westward, and along the Sulemán range to the eastward.

Variation in cretaceous deposits.

The cretaceous beds in these two not very distant localities differ totally in character, and are in both places perfectly distinct from the formations of the same or nearly the same geological age observed in the Laki hills of lower Sind. The eocene strata are less variable, although there are constant changes in the position and thickness of the limestones. The later tertiary beds are more constant in character.

List of strata.

The following is a list of the subdivisions observed. Owing to the differences in distribution just mentioned, the strata of the neighbourhood of Quetta, including the Bolán and Harnai routes, are placed in a different column from those of the Sulemán range :—

List of Geological Sub-divisions observed around Quetta and in the Sulemán Range.

Systems or major Divisions.	Subdivisions.	Quetta and neighbourhood.	Approximate maximum thickness.	Sulemán.	Approximate maximum thickness.	Geological age.
5. RECENT and POST-PLIOCENE.	. . .	Sands and fine loam of plains. Gravels and conglomerates of slopes, &c.	?	Alluvium of Indus valley. Gravels of slopes, &c.	?	*Recent and post-pliocene.*
4. SIWALIK or MANCHHAR.	Upper .	Sandstones, clays, and conglomerates of base of hills and of plateau.	7,000	1. Conglomerates. 2. Sandstones and clays with conglomeratic bands.	2,500	*Pliocene.*
	Lower .	*Wanting* . .	. .	Sandstones, clays, marls, bone beds, &c.	5,000	*Upper miocene.*
3. NARI . .	Upper .	*Wanting* . .	. .	Sandstones, clays, &c.	2,000	*Miocene.*
	Lower .	Brown limestone of Bibi Náni.	?	*Wanting* . .	. .	*Oligocene.*

List of Geological Sub-divisions observed around Quetta and in the Sulemán Range—(continued.)

Systems or major Divisions.	Subdivisions.	Quetta and neighbourhood.	Approximate maximum thickness.	Sulemán.	Approximate maximum thickness.	Geological age.
2. EOCENE	Upper	Nummulitic limestone.	3,000	Olive clays, shales, sandstones, &c., with a few thin bands of nummulitic limestone.	8,000	*Eocene.*
	Lower	Olive shales, clays, sandstones, &c., a band of limestone breccia at or near the base.	3,000?	Coarse brown sandstone with a band of limestone breccia.	1,000	
1. CRETACEOUS	. .	1. Black compact limestone.	200	1. Hard whitish sandstone grit.	1,500	*Cretaceous.*
		2. Variegated limestone shales.	500			
		2a. Conglomerate of volcanic pebbles. Basalt (local).	1,000	2. Dark-grey limestone passing downwards into limestone shales.	1,000 seen.	
		3. Dark grey limestone.	1,000			
		4. Pale limestone	500 seen			

Geological observations imperfect.

It should be remembered that the examination of the country traversed was of the most cursory and superficial description, and had not the geology in general been exceptionally simple, no adequate idea could have been gained of the structure. In places, as in the neighbourhood of Quetta, and of a portion of the Harnai route, where the geological features are a little more intricate, further examination is required before the characters and distribution of the formations can be thoroughly understood. The map compiled is simply a sketch without any pretension to exactness in detail; some of the geological boundaries having been inserted on the strength of observations made at a distance of several miles. But with a surface so utterly destitute of any concealment by vegetation, the colour and

appearance of particular beds can be recognised through the clear atmosphere of these dry desert regions at very great distances, and the certainty with which geological boundaries can be traced for miles, if seen from an elevation, would scarcely be credited by geologists who have not had experience of similar areas.

Thickness of beds.

The thicknesses assigned in the preceding table are as a rule mere guesses, and are chiefly intended to show the relative development of different stages and beds. The aggregate given above of about 17,000 feet near Quetta and 21,000 in the Sulemán range is as likely to be too low as too high. The thickness of each subdivision varies considerably.

Cretaceous.

1. *Cretaceous beds.*—As already more than once pointed out, there is a wide difference between the representatives of this system near Quetta and those exposed in the Sulemán range. The former will first receive notice.

Cretaceous rocks of Quetta.

The lowest bed seen by me in the neighbourhood of Quetta is the limestone of the hills due south of Sir-i-áb and about 10 miles south of Quetta itself. These hills consist of an anticlinal of pale coloured, often cream-coloured or pale pinkish-grey limestone, very homogeneous and fine-grained. In the hill range to the east of the Quetta plain, not visited by me, Mr. Griesbach found hippurites[1] in abundance in strata which he considered a little lower than those exposed in the Sir-i-áb hills. The latter are precisely similar to some of the limestone with hippurites found to the westward in Persia. A few hundred feet of this rock are seen near Sir-i-áb, the base not being exposed. Fossils do not appear very common, but they may be more abundant locally.[2]

Pale limestone.

[1] Mem. G. S. I., Vol. XVIII, p. 36. A section through the hills near Sir-i-áb is represented on p. 37. The relative thickness of the different beds in this section (fig. 8, and also in the upper fig. 7) is not correct, and as the scale of heights is much greater than that representing horizontal distance, the general effect is not exactly the same as that of the rocks *in situ*.

[2] Mr. Griesbach found *Inoceramus* and corals in these beds (*l. c.* p. 36), but, as I understand, not in this locality.

The next limestone in ascending order is very dark coloured, often black or blackish grey. It is hard and massive, and forms the greater portion of the slopes on the hill ranges east and west of the plain south of Quetta. South-west of Sir-i-áb this dark coloured limestone appears clearly to overlie the paler coloured homogeneous limestone just described. The thickness of the dark limestone[1] is considerable, probably not less than 1,000 feet and possibly more, but time did not admit of any measurement. To the westward higher rocks come in above the dark limestone. To the southward, the same dark cretaceous limestone forms the greater part of the hills on the sides of the Dasht-i-Bedaolat, and is traversed by the road between Dozán in the Upper Bolán Pass and Darwáza or Dasht.

Dark limestone.

Above the dark massive limestone there is a considerable thickness, probably not less than 500 feet near Quetta, of some very characteristic strata, fine-grained shaly or flaggy limestones and calcareous shales[2] of various colours, chiefly white or cream-coloured, variegated with purplish red or alternating with bands of that tint. No recognisable fossils were found. These calcareous shales are well seen (1) at Dozán in the Upper Bolán Pass; also (2) on the skirts of the hills east of the road between Darwáza and Sir-i-áb, south of Quetta, about 6 or 7 miles north-west of Darwáza; and (3) in the Chehiltan range south-west of Quetta.

White and variegated limestone shales.

Similar beds are also seen near Kach and Amadun, about 25 miles north-east of Quetta, associated with a great development of basaltic formations, partly detrital, but partly, to all appearance, consisting of solid igneous rock. The latter may be intrusive. The sections will be described in more detail in Chapter VI, in which the observations made on the Harnai route between Quetta and Sibi will be recapitulated. Near

Cretaceous beds of Kach and Amadun.

[1] This dark limestone is the No. 2 or *Inoceramus* limestone of Mr. Griesbach's sections, pp. 34, 35, and of his figs. 7 and 8, p. 37. It is also No. 1 of his Profile 1, plate IV. This profile gives a better idea of the geology than the sections on p. 37.

[2] No. 3 of Griesbach, pp. 34, 35 and figs. 7 and 8, p. 37. No. 2 of Profile 1, pl IV.

Kach camp, on the road to Gwál, the variegated limestone shales dip at a high angle and appear to underlie a bed of basalt or anamesite, apparently interstratified. The dip is probably reversed and the variegated limestone shales may be the newer formation. Further on upon the same road the variegated limestone shales are distinctly seen overlying a mass of basalt. A few miles further to the north-east from Kach, near Amadun, the limestone shales overlie (apparently underlie, but the dip is again reversed) a mass of conglomerate, probably 1,000 feet thick, entirely composed of rolled doleritic pebbles. This is succeeded in descending order by massive limestone of great thickness, probably the same as the dark cretaceous limestone of the hills near Quetta. The relations of all these beds near Kach to those near Quetta are not absolutely certain, as will be shown presently.

Volcanic rocks.

Conglomerate of doleritic pebbles.

The uppermost bed that I refer to the cretaceous system near Quetta is the hard, black, massive, compact limestone[1] above the variegated limestone shales. This bed is admirably seen, and from its dark colour and hardness forms a conspicuous band on the Chehiltan range south-west of Quetta, where the thickness is probably about 150 feet. The same bed, probably rather thicker, is well exposed in the Bolán Pass below Dozán.

Hard, black, compact limestone.

No recognisable fossil was obtained by me from this bed, and the only reason for assigning it to the cretaceous rather than to the eocene system is that in appearance and mineral character it resembles the limestones of the latter much more than those of the former, that it contains no nummulites, and that in the Bolán Pass it underlies beds containing a peculiar limestone breccia which is certainly very close to the base of the eocene system. The black compact limestone was not found near Kach. All the beds near Quetta from the black limestone downwards, appear to be conformable to each other.

The cretaceous rocks of the Sulemán range differ so widely from

[1] No. 4 of Griesbach, pp. 34, 35, Ostrea limestone of sections 7 and 8, p. 37, and No. 3 of Profile 1, pl. IV.

those of Quetta that before leaving the latter a few words on their relations to the rocks of the same age in other parts of Asia are desirable.

Relations of Quetta cretaceous beds.

Hippuritic limestone.

The two lower beds in the section, the pale-coloured and the dark-grey limestone, are, I think, clearly upper members of the great hippuritic limestone group. This is I believe Mr. Griesbach's view also. Very similar limestones were found by him [1] to form the ranges near Kándahár, and precisely the same rocks, sometimes quite unfossiliferous, but locally abounding in *Hippurites*, are widely exposed in Persia [2] from Karmán to Teherán. To the eastward hippuritic limestone is known to occur at Siasgai peak, 70 miles east-north-east of Quetta, [3] and there is great probability that the cretaceous beds generally are well developed in the ranges north of the Harnai route around Kawás and Chinján. The limestone with *Hippurites* found in the Laki range of Sind [4] may be of the same age, but there, as in the Sulemán range, the whole section is so different that the different stages cannot at present be recognised.

Doleritic conglomerate.

The conglomerate of doleritic lava pebbles found near Amadun precisely corresponds to the description given by Mr. Griesbach of similar deposits observed by him west and north-west of Kándahár at Kotal-i-Murcha, Kohkarán, &c., in the range between the city and the Argandáb valley. The beds above the conglomerate, greenish sandstones overlying green and red shales, in the section given by him [5] have some remarkable points of resemblance to those near Amadun, where, above the doleritic conglomerate, variegated limestone shales occur, and over these again the greenish sand-

[1] *L. c.*, pages 39-45.

[2] Eastern Persia, Vol. II, pp. 457, &c.

[3] Proc. A. S. B., 1879, pp. 202: see *ante*.

[4] Mem. G. S. I., Vol. XVII, pp, 17, 133.

[5] *L c.*, p. 42. " 3. A shaly sandstone made up more or less of trappean material.

"2. Bright coloured green and densely red shales with thin sandstone beds of trappean substance.

" 1. Conglomerate, coarse and in great thickness almost entirely made up of pebbles of trap, and cemented together by a trappean though calcareous matrix."

stones and sandy shales at the base of the eocene, the latter being precisely the beds which Mr. Griesbach looks upon as o rmed of trappean detritus near Quetta. But the Kándahár beds are said to be lower cretaceous and inferior in position to the hippuritic limestone. If this is correct, either the beds near Amadun cannot be the same as those near Kándahár, or the identification of the variegated limestone shales with those of the upper cretaceous beds at Quetta is erroneous. The circumstance that, as will be shown hereafter, the eocene beds at Kach near Amadun are unconformable to the cretaceous certainly renders it possible that the latter may belong to a lower and not to the upper subdivision of the system, but it is more probable that the view taken above of the relation between the Kach and Amadun beds and those of Quetta is correct, and that the variegated limestone shale at both places is identical.

Limestone shales.

The white and variegated limestone shales of Quetta do not appear to have been observed further west, unless, as above suggested, they are represented by the green and red shales of Kándahár. This suggestion, however, is merely indicated as possible. There is much more reason to believe that these calcareous shaly and flaggy beds are identical with those observed on the upper Gáj river, west of the Sind frontier,[1] with similar beds found by Dr. Cook[2] at several places south and south-west of Kalát, and with some greenish-white and pale purple calcareous shales seen at Gadáni,[3] on the Baluchistan coast, about 25 miles north-west of Karáchi. In the first-named locality on the Gáj river the limestone shales are in the same position as near Quetta, just below beds of eocene age, and the same is the case, according to Dr. Cook, in the country south and south-west of Kalát. At Gadáni, where the relative position was not ascertained, basalt and dark-grey or blackish limestones were found in the immediate neighbourhood, showing a remarkable resemblance to the association of rocks at Kach near Quetta.

[1] Mem. G. S. I., Vol. XVII, pp. 42, 98.
[2] Trans. Med. Phys. Soc., Bombay, 1860, No. VI, p. 100.
[3] Mem. G. S. I., Vol. XVII, p. 189.

The trap noticed by Mr. Griesbach in the Upper Bolán Pass must, I think, as already stated in the first chapter of this Memoir,[1] be associated with the limestone shales.

Relation of volcanic rocks to Deccan traps.

It is highly probable that the upper cretaceous doleritic rocks near Quetta are of contemporaneous origin with a portion of the Deccan traps. But I am not at all sure that any of the former "represents the trap horizon of Western Sind," although Mr. Griesbach thinks there is no doubt of the fact.[2] The traps of the Deccan appear to extend in age from upper cretaceous to lower eocene,[3] and although I am inclined to class the Quetta volcanic rocks with the former, the trap of Western Sind may perhaps be of very early tertiary age. To this subject it will be necessary to revert presently when discussing the eocene beds.

Boundary near Quetta between tertiary and cretaceous.

The boundary near Quetta, between the cretaceous and eocene beds, is drawn upon undoubtedly imperfect evidence. That the lowest beds referred to the eocene system in the Upper Bolán section, on the Chehiltán range west of Quetta, and near Kach, are tertiary, admits, I think, of little, if any, doubt, and all the limestones beneath the variegated calcareous shales may be, I believe, safely referred to the cretaceous period. The only question is with regard to the variegated limestone shales themselves and the overlying black limestone. The very marked break in character between the latter and the olive eocene shales, and the fact that these olive shales near Kach are distinctly unconformable to all underlying beds, including the limestone shales (the compact black limestone is wanting), besides the points already mentioned, the absence of nummulites in the supposed cretaceous limestone, and its mineral

[1] *Ante* p. 17.

[2] *L. c.*, p. 51. In this and numerous other cases it is to be regretted that Mr. Griesbach has expressed himself so confidently as he has done.

[3] Manual of the Geology of India, p. 329. Some recent researches of Mr. Bose, noticed by Mr. Medlicott, Rec. G. S. I., Vol. XV, 1882, p. 5, appear to indicate a rather later age for the lowest Deccan traps. I have gone over the evidence very briefly, but it does not appear to me that sufficient reason has been shown for classing any of the fossiliferous beds beneath the trap at Bág as of later date than the Trichinopoly beds (lower Chalk or Turonian), and they may be Cenomanian. If so, the lower traps are probably upper cretaceous.

character, are opposed to the classification of these rocks as eocene. It should not be forgotten also that Dr. Cook[1] found ammonites south of Kalát, in beds very probably identical with the limestone shales of Quetta.

Cretaceous of Sulemán range.

In the Sulemán range the supposed cretaceous beds comprise two well-marked stages. The lower of these was only observed in the deep ravines cut by streams into the main range itself, and was actually examined in but two localities; the deep gorge of the Kaha stream, west of Harrand, and that excavated by the head waters of the Choti stream, immediately south of the road to Fort Munro, the sanitarium of Dera Gházi Khán. This lower stage consists of dark grey limestones, occasionally sandy or shaly, passing down into calcareous shales, dark-grey to bluish-grey in colour, and often nodular. The bottom of these was not seen, and the whole thickness of limestone and shale exposed must have been about 1,000 feet in each of the sections examined.

Grey limestone and calcareous shales.

Fossils.

The limestone abounds in indistinct fossils, especially *Foraminifera*, but none were found that could be determined at the time. In the underlying shaly beds, however, two species of *Exogyra*, one or two of *Inoceramus*[2] and a Cephalopod were found. The latter is so poorly preserved that not even the genus can be ascertained; it doubtless belongs to the *Ammonitidæ*, and the last whorl appears to be protracted somewhat as in *Hamites*, whilst the upper whorls may have been free as in some *Turrilites*. All the whorls are transversely ribbed. The *Inoceramus* is a form with concentric ribs and fine striæ parallel with the ribs. The *Exogyræ* are more characteristic. One species is nearly allied to *E. suborbiculata*, Lam., and is also near the well-known *E. columba*, Lam.; the second species is near *E. ostracina*,

[1] *L. c.*, also Mem. G. S. I., Vol. XVII, p. 43.

[2] I am indebted to Dr. Feistmantel for assistance in making out these. In explanation of the very imperfect identification given, it is necessary to explain that the fossils are in Calcutta, whilst this paper is being written in England, and that I was unable to compare the specimens whilst in Calcutta.

Lam. All these species of *Exogyra* are middle cretaceous, and both the *Inoceramus* and Cephalopod are cretaceous rather than jurassic types.

The *Inoceramus* is the commonest and most characteristic fossil; some of the shells found measure 6 inches across, and the two valves often occur together, though wide open.

Upon the limestones, apparently conformably, hard sandstones and grits are deposited, about 1,500 feet thick, generally pale coloured, white or whitish, not unfrequently speckled with brown, and occasionally pale-greenish, bluish-green, or purplish. A few thin beds of dark shale occur, but they are infrequent. From their hardness and pale colour, these rocks are very conspicuous, and they form a considerable proportion of the eastern slope on the Sulemán main range. No fossils have been found in them.

Hard whitish sandstones.

No unconformity can be detected between the hard whitish sandstones and the beds above and below them. The limestones beneath are sandy towards the top, and there is in places intercalation of sandstone layers between the uppermost beds.

Neither of the stages described above can be identified with any known cretaceous formation. There is not much similarity between them and the poorly developed representatives of the system in the Trans-Indus continuation of the Salt Range, though the soft white supra-jurassic sandstone of Shekh Budín,[1] may perhaps, although greatly dwindled in size, be the same bed as the hard whitish sandstones of the Sulemán range. The sandstone of Shekh Budín has nowhere been observed to exceed 200 feet in thickness, and its relations to the jurassic beds beneath it appear somewhat doubtful, for Mr. Wynne, whilst classing it provisionally as cretaceous, suggests that it may be partly even post-eocene in age.

Relations to other cretaceous beds.

None of the passage beds between the eocene and the cretaceous in Sind present much resemblance to the hard whitish sandstones of the

[1] Wynne, Mem. G. S. I., Vol. XVII, pp. 79-84.

Sulemán range, and the limestones of the former area are quite different from those of the latter. It is highly probable that the sandstones[1] beneath the *Cardita beaumonti* beds in the Laki range of Sind may be on nearly the same geological horizon, but there is no sufficient evidence for correlation. The only sandstones known in India, so far as I am aware, that distinctly resemble the Sulemán beds in mineral character, are those forming the lower portion of the Bág beds[2] in the Western Nerbudda valley, and especially those exposed on the Deva stream in the Rájpipla hills. But these sandstones, although cretaceous, are probably older than those in the Sulemán range.

Probable age of Sulemán sandstones.

The reason for assigning the Sulemán sandstones to the cretaceous system is that, near the bottom of the next overlying stage, the peculiar band of limestone breccia occurs, that, in so many places, appears to mark the base of the eocene. The limestones underlying the hard white sandstones appear to be cretaceous, and the fossils show some resemblance to those of the upper green sand (Cenomanian).

General description of eocene beds.

2. *Eocene.*—The eocene beds present no such difficulties as the cretaceous, nor, although their character is very far from uniform, do they vary so widely in different parts of the areatraversed as the under lying beds. A fair general description of them is that they consist of olive shales, more or less sandy or calcareous in parts, with beds of nummulitic limestone, varying in thickness and in position, but so developed occasionally as to occupy the greater portion of the whole system, the shales becoming merely subordinate. This is the case in the Bolán Pass and north of Quetta, whilst elsewhere, as east of the Sulemán range, nearly the whole thickness of the system consists of shales; beds of limestone being only found at rare intervals and a few feet in thickness. Soft sandstones are often intercalated with the shales, and in the Sulemán range the lowest part of the whole system is composed of hard brownish and purplish sandstones, about 1,000 feet thick,

[1] Mem. G. S. I., Vol. XVII, pp. 32, 34, 129, &c.
[2] *Ibid*, Vol. VI, pp. 207-219, &c., and Manual, page 295.

amongst which a few beds of shale or of limestone are intercalated. One of the limestone bands close to the base is the very peculiar limestone breccia already referred to somewhat frequently. It consists of dark-grey angular limestone fragments in a somewhat paler limestone matrix. Both fragments and matrix contain small *Nummulites* and sometimes *Alveolinæ*, and no constant difference has been traced between the forms found in the two portions of the rock. This bed does not appear to be more than 30 to 40 feet thick, and it has been observed near Quetta and also on the Sind Frontier, at the Gáj river, as well as in the Sulemán range.

Limestone breccia of lower eocene.

The eocene is, taken altogether, the most important system on the frontier of Western India. In Southern Afghanistan it is seldom, if ever, less than 5,000 to 6,000 feet thick, and it is probably in places as much as 9,000 feet, if not more.

Thickness of eocene.

To show the variation in character of the eocene beds it will be useful briefly to pass them in review from Sind to the Punjab, calling attention also to the change in characters that takes place to the westward.

Variation.

Southern Sind eocene.

The eocene rocks of Southern Sind[1] consist of the following in descending order:—

STRATA.	THICKNESS.
Khirthar limestone.	. Variable, not exceeding 500 feet.
Ranikot sandstones, shales, and clays, with bands of brown limestone near the top.	. About 2,000.
Deccan trap.	. Variable, 40 to 90.
Cardita beaumonti beds: olive shales and limestone.	. 350 to 450.

[1] Mem. G. S. I., Vol. XVII, pp. 39, 46, 128, &c. The Nari oligocene beds are not here included in the eocene system.

In Cutch the eocene beds above the Deccan trap are thus classified by Mr. Wynne:—

Nummulitic group, white and yellow limestones with marls and sandy beds	700 Feet.
Gypseous shales	100 "
Subnummulitic group, variegated argillaceous beds highly coloured	100 "

Mem., G. S. I, Vol. IX, p. 48.

The latter, with the overlying band of basaltic trap, I have hitherto classed as cretaceous.[1] The fauna, however, so far as it has hitherto been examined critically,[2] seems to show that, although there is an admixture of forms with cretaceous affinities, eocene types predominate, and the olive shales agree in mineral character with rocks characteristic of the eocene period in Western India. It appears therefore advisable to class these *Cardita beaumonti* beds as the lowest tertiary; they are perhaps inferior to any known eocene stage found in Europe, for the Echinoderms of the Ranikot beds, as shown by Dr. Martin Duncan,[3] are older in facies than the lowest Echinoderm fauna known from the tertiary beds of Europe and North Africa, whilst the *Cardita beaumonti* beds are 1,500 feet below the fossiliferous Ranikot strata.

Eocene of Khirthar range.

About 60 miles further north than the Laki hills, where the section last quoted was observed, the eocene rocks in the Khirthar range separating Upper Sind from Baluchistan consist of a mass of nummulitic limestone, 1,000 to 3,000 feet thick, resting upon olive and brown shales, clays, and sandstones with bands of limestone, generally containing nummulites, intercalated. In the only place where the thickness could be estimated, on the Gáj river, the section was :—

Nummulitic limestone	1,200
Shales and sandstones, with bands of limestone in places : about	4,000

Bolán Pass.

In the Bolán Pass the section is similar, massive nummulitic limestone above, shales and sandstones, often of an olive colour, below. It is very difficult to estimate the thickness of the nummulitic limestone, and the upper portion probably suffered from denudation before the overlying Upper Siwalik beds were deposited, but the remaining thickness must be at least 1,000 feet in

[1] Manual of the Geology of India, p. 447, &c., Mem. G. S. I. Vol. XVII, pp. 32-33, &c.
[2] The corals and echinoderms have been described by Dr. Martin Duncan with the assistance, for the latter, of Mr. Percy Sladen. See Palæontologia Indica, Ser. XIV, Vol. I, Pts. 2-3.
[3] Pal. Ind., XIV, Vol. I, pt. 3, page 99.

places, though perhaps rather less in the Lower Bolán Pass itself between Kohandiláni and Kirta. The limestone is of the usual character, rather massive in general but occasionally distinctly stratified, pale-coloured, usually whitish or light-grey, rarely dark-grey, and often abounding in nummulites and other *Foraminifera.* One variety, described by Mr. Griesbach,[1] has a concretionary structure and simulates conglomerate; this bed is well seen just above Kohandiláni. A similar bed is not uncommonly met with in the nummulitic limestone of Northern Sind.

The lower eocene shales and sandstones in the Bolán Pass comprise several thin beds of coal,[2] particularly well seen about Mach near Sir-i-Bolán, associated with bands of impure limestone containing *Cyprina* and other bivalve shells, *Turritella,* &c. Many of the species have an estuarine facies. Towards the base are some dark-coloured limestones containing *Nummulites* and other *Foraminifera,* one of these beds being the breccia already noticed.

Coal-bearing beds of Mach.

The country north of the Upper Bolán Pass around the great Zirghun mountain has not been examined, but the same arrangement of limestone above and shales below occurs in Takátu mountain north of Quetta, where, however, the thickness of both the limestone and the shale appears greater than in the Bolán, and neither can be less than 3,000 feet in thickness. To these sections it will be necessary to recur presently.

Country north of Upper Bolán Pass.

West of Quetta a great change takes place. In the Chehiltán or Karaksar range south-west of the town, all the upper portion of the eocene system is composed of limestones with shaly and sandy beds intercalated, the whole being very different from the massive limestone of Takátu. At the base, in the Chehiltán range, there are about 1,500 feet of olive shales resting on the black compact upper cretaceous limestone. In the next range to the westward, that of Mashalik (or Dinár), it is probable that the upper limestone

Eocene west of Quetta.

[1] *L. c.*, p. 30.
[2] Mem. G. S. I., Vol. XVIII, p. 23. Rec. G. S. I., Vol. XV, 1882, p. 149.

of Takátu is not represented, the only limestone that I saw is in bands of no great thickness, and similar in character to the beds intercalated in the olive shales forming the lower part of the system, except that it is darker in colour than they usually are to the eastward.[1] The associated shales and sandstones are turned on end and greatly hardened, some being almost slaty. The hardening and contortion, according to Mr. Griesbach,[2] are conspicuous in the much higher range a little further west, known as the Amrán, and crossed by the Kojak Pass on the road to Kándahár. Here also no great bed of nummulitic limestone was observed, although bands of considerable thickness are intercalated. Mr. Griesbach calls attention to the resemblance between these shales and sandstones and the flysch of the Alps.

Relations to beds of Takátu.

There appears every probability that the thick limestone of Takátu, partially broken up into shaly and sandy beds in the Chehiltán range, disappears to the westward, and is replaced by shales and sandstones, precisely as takes place with the Khirthar limestone in South-Western Sind.[3] The "flysch" character of the eocene rocks is highly developed in the western part of Baluchistan, and some of the enormous series of vertical or nearly vertical beds seen between Gwádar and Jalk on the edge of the Sistan desert[4] closely resemble the beds of the Mashalak range west of Quetta.

"Flysch" of Baluchistan.

Eocene east of Takátu.

Passing eastward from Takátu, along the Harnai route from Quetta to the plains, the olive shales, clays, and sandstones of the lower eocene appear to increase in thickness. Some beds of dull Indian red shale or clay are intermixed and become more conspicuous further east. Occasionally bands of limestone, usually

[1] As I have already suggested (Manual of the Geology of India, p. 511), it is not improbable that the nummulitic limestone assumes a darker colour where it has undergone pressure and disturbance; certainly wherever the associated beds are turned on end, hardened, or contorted, so far as I have seen, the limestone is darker coloured than it usually is when but little disturbed.

[2] *L. c.*, p. 82.

[3] Mem. G. S. I., Vol. XVII, pp. 47, 176.

[4] Eastern Persia, Vol. II, p. 461. Jalk is about 300 miles south-west of Quetta.

pale coloured, abounding in *Nummulites* of several species, and often containing *Alveolinæ*, *Orbitoides*, and other *Foraminifera*, attain a considerable thickness. One such band forms the ridge of Nár, 12 miles north-east of Quetta.

Near Kach and Amadun.

The basement beds of the eocene system near Kach and Amadun, about 25 miles north-east of Quetta, are olive shales and sandstones, with some beds of conglomerate, containing pebbles of sandstone, grit, limestone and chert. These beds rest quite unconformably on the cretaceous beds above described, and are overlain by the nummulitic limestone of the Pil range, east of Kach. The junction, it may here be mentioned, is the only instance of unconformity between eocene and cretaceous beds yet observed in the countries adjoining the Sind frontier.

Eocene beds on Harnai route east of Kach.

Unfortunately in the hurry of travel[1] the sections of eocene beds exposed in the hills bordering the Harnai route received but a very imperfect examination. Zarghun, the great range already noticed as lying east of Quetta and north of the Upper Bolán Pass, and which intervenes between the upper parts of the Bolán and Harnai roads, appears to be, like Takátu, formed of a very thick mass of nummulitic limestone overlying the lower eocene shales and sandstones. This nummulitic limestone in the Bolán Pass is the highest eocene bed seen. In the Harnai route, south-east of Harnai and on the road from Quat-Mandai to Thal Chotiali, the eocene beds exposed below the base of the Siwaliks are (the thicknesses being little more than guesses) :—

	Thickness at Spintangi.	Thickness at Tang.
a. Olive shales and sandstone	4,000 ?	1,000
b. Nummulitic limestone	300	1,000
c. Olive shales and sandstone	1,000	?
d. Nummulitic limestone (apparently of great thickness)	?	?

Throughout the Harnai route below Kach the lower nummulitic limestone *d* forms immense hills, including the Pil and Chappar ridges, the

[1] And, in part, in consequence of illness.

upper part at least of the huge mountain mass north of Sháhrág and Harnai, and a number of hog-backed elongate hills of smaller elevation. All these different ridges are anticlinal, except the Pil range, west and north-west of which the olive shales at the base of the eocene system are seen to underlie the lower limestone.

Correlation of thick limestone beds.

The question that presents itself is whether this massive limestone is the same as that of the Bolán Pass and Takátu' that is, whether the position in the system is identical in both cases. If it is, the overlying shales and limestone *a*, *b*, and *c* have been denuded to the west and south-west about Quetta and the Bolán. But if the limestone of the Pil range be the same as that of Zarghun, it should be distinctly seen to cross the valley below Kach; and although the outcrop may have been overlooked, I do not think it was. It is more probable that the massive limestone of Pil, Chappar, &c., is an expansion of the lower limestone seen intercalated in the shales near Gandak, north-east of Quetta, and that the great overlying limestone of Takátu and the Bolán route disappears and is replaced by shales and sandstones to the eastward.

Coal-bearing beds of Sháhrág.

The shales and sandstones, with occasional beds of limestone, that overlie the massive limestone *d* appear to be greatly developed about Sháhrág, where they occupy a valley about 10 miles broad. It is probable that they are folded so as to cause repetition of the same beds, otherwise the thickness exposed would be enormous, for the dip is generally high. Some beds of coal,[1] associated with occasional bands of impure fossiliferous limestone, intercalated in a series of soft sandstones, shales, and clays are found in this neighbourhood south and east of Sháhrág, and both the coal beds and their

Relations to beds of Mach in Bolán Pass.

associated rocks precisely resemble the strata of Mach near Sir-i-Bolán on the Bolán route. The Mach seams do not appear to be much more than 1,000 feet above the base of the eocene system, while below the Sháhrág beds there are the shales, &c., of the Sháhrág plain, assuredly not less than 2,000 feet in

[1] A measured section of these and the associated strata will be found in Chapter VI.

thickness, and probably considerably more, together with the thick limestones of the range to the northward, and perhaps more shales below the limestone. Further examination of the country is necessary before the horizon of the Sháhrág coal seams can be determined with certainty, but sufficient is known to render it probable that these beds, despite their close resemblance to those of Mach, may be considerably later in age.

Eocene beds of Bugti hills.

The eocene strata of the Mari hills have not been examined, and in the Bugti hills, except to the eastward near the Punjab frontier, only the upper stages were observed. In the western part of the hills, near Lehri and Pulaji, the upper beds of the system consist of limestone with *Nummulites* and *Alveolinæ*, but there appears to be a gradual diminution of the limestone to the eastward. It should be mentioned that no denudation appears to have affected the uppermost beds before the deposition of the Siwaliks in the Bugti hills, and also in the Sulemán range further east, the latter strata being conformable and not resting on an apparently worn and denuded surface as in the Bolán Pass. South of Bugti Dera the uppermost beds are—

1. Shaly limestone containing small nummulites (*N. ramondi ?*)	About 50 feet.
2. Pale olive shale, with reddish brown (coffee-coloured) bands.	Several hundred feet.
3. Nummulitic limestone, more massive.	

Sham plain.

To the north of Bugti Dera the limestone (No. 1) is much thicker than to the south. Further east, however, north of Gandahári (Gehandári) hill this bed disappears altogether. South and east of the Sham plain, and thence to the northward, along the flanks of the Sulemán range, the limestones are only represented by thin bands, each usually not more than 20 to 30 feet thick, and in many places it is very doubtful if 100 feet of limestone occurs altogether in the whole system from top to bottom, whilst one of the most persistent and conspicuous bands is formed by 2 or 3 beds of white gypsum, about 15 to 20 feet thick in the aggregate, that underlie the principal and most continuous of the limestone bands. This limestone band is a continuation of that forming the surface of Gandahári hill and is about 500 to 1,000 feet below the top of the eocene.

The Sham plain, like many other plains[1] to the northward and north-westward, is composed of soft shales and sandstones dipping at a low or moderate angle. The ranges that separate these plains from each other generally consist in part of the harder calcareous bands.

Eocene of Sulemán range.

The section of the eocene beds on the east flank of the Sulemán is approximately the following:—

	Feet.
(a) Shales, chiefly olive, with sandstones and a few thin beds of limestone	7,000 to 9,000
(b) Hard brown sandstones with a band of limestone breccia near the base	1,000

These sandstones (b) are a new feature in the eocene system. They

Brown sandstones.

form a great part of the surface on the main range of the Sulemán. They are in general of rather coarse texture, compact, and very hard, usually ferruginous brown in colour, sometimes purplish, and often pale with dark red or brown spots. There is some resemblance between them and the sandstones beneath the *Cardita beaumonti* beds of the Laki range in Sind,[2] but the latter are much softer. In some places a band of limestone containing oysters was seen associated with the sandstones in the Sulemán range as in Sind.

The limestone breccia of the Sulemán is precisely similar to that

Limestone breccia.

already described as occurring near Quetta and elsewhere, and as it is clearly interstratified with the sandstones at some distance above their base, it serves to mark the horizon and to show that in all probability not only are the brown sandstones eocene, but very low eocene, and the underlying white sandstones are probably to be referred to the cretaceous epoch as already stated.

The small quantity of limestone in the nummulitic system through-

Increase of limestone to northward.

out the southern portion of the Sulemán range is remarkable. In the northernmost part of the

[1] These plains are much more extensive, and the intervening ranges less conspicuous and of smaller dimensions, than the hill shading on the map would lead any one to suppose.

[2] Mem. G.S.I., Vol. XVII, pp. 34, &c.

area examined, near the base of Saronk, the limestone in the eocene beds appears to increase again, and in the Soundhra or Sangarh stream a band between 200 and 300 feet thick is cut through. This band is in the middle of the system, having a great thickness of shales both above and below; it continues to the northward, and forms a well-marked ridge known as the white range.

West of Sulemán.

To the west of the Sulemán also, as was clearly shown by Mr. Ball,[1] the limestone is much better developed than to the eastward. A thick bed of limestone, measuring approximately 700 feet, is seen capping the sandstones and shales. But it by no means follows that the limestone was originally the uppermost member of the eocene system; more probably here, as in so many other places, and especially east of the Sulemán, the highest beds were shales and sandstones, overlying the principal calcareous band, but the soft overlying strata have been removed by denudation. The coal-bed of Chamarlung is shown by Mr. Ball to be just beneath the limestone, and consequently rather high in the system, probably above rather than below the middle. A great thickness of shales, sandstones, &c., probably 5,000 to 6,000 feet, must underlie the coal horizon, which may perhaps be the same as that of Sháhrág on the Harnai route, but is more probably later, and which certainly appears to be considerably higher in the system than that of the Mach or Sir-i-Bolán coal. So far as the evidence extends, it is rather in favour of very similar beds recurring in various localities at different horizons.

Coal of Chamarlung.

Eocene of Northern Punjab.

Shekh Budín.

Northward of the area visited on the flanks of the Sulemán range there is a break of nearly 100 miles before reaching the limits of Mr. Wynne's work near Shekh Budín. In the hill ranges extending thence along the western side of the Indus, the eocene system is poorly seen, as at Shekh Budín itself, where the system is represented to consist of limestone below, with shales clays and sandstones above;

[1] Rec. G.S.I., Vol. VII, p. 151.

and it appears to be entirely absent in places. Finally, in the Salt-range east of the Indus, the section[1] consists of

Salt Range.	(a) Pale limestone . . .	400 to 600
	(b) White sandstones, shales, and red and grey clays with lignite and gypsum . .	150 to 300
	(c) Olive, reddish and white sandstones.	150 to 200

The latter have hitherto been considered probably cretaceous and perhaps with reason, but it is on the whole quite as probable that their upper members may be eocene, like the other olive beds. The boulder bed at the base of the group may, however, very possibly be older.

Hazára and Murree.

North of this, in Hazára, the eocene system is chiefly composed of thick dark-coloured limestone, whilst the calcareous element again diminishes in quantity near Murree and the Jhelum valley. In the same beds of the Upper Indus valley, Ladák, much further to the northward, scarcely any limestone occurs, and the strata, although contorted and indurated, appear to be not dissimilar in character to the shales and sandstones of the hills on the south-west Punjab frontier. Near Simla, much further east, the Subáthu nummulitic beds agree in character, to judge from the description, with the soft olive brown and red shales, clays, and sandstones of the Sulemán range.

Ladak.

Subáthu near Simla.

3. *Nari.* (*a*) *Lower Nari or Oligocene.*—The lower Nari or oligocene limestone, so well and constantly developed in all parts of Western Sind,[2] except the south, was only detected at one place to the northward. This was in the hills immediately north of Bibi Náni (2 or 3 miles north-west of the military post bearing that name) near the Bolán route. At this place the typical brownish limestone (orange brown to wood brown) occurs resting, to all appearance conformably, on whitish or grey eocene limestone, the

Lower Nari beds.

[1] Mem. G. S. I., Vol. XIV, p. 69. Manual of the Geology of India, p. 481.
[2] Mem. G. S. I., Vol. XVII, pp. 49, &c.

Nari limestone containing the typical *Nummulites sublævigata*, *N. garansensis*, and *Orbitoides papyracea*. There was no opportunity for examining the spot carefully, and it is doubtful whether any of the higher Nari beds are found, although some variegated strata, seen on a neighbouring hill, may represent a portion of them.

Not a trace of the oligocene limestone was detected east or north of the locality named, and it appears now somewhat doubtful whether the oligocene sea extended further to the northward.[1]

Upper Nari beds.

3. (b) Upper Nari.—No rocks representing the Upper Nari beds of Sind were seen on the Bolán or Harnai routes, nor throughout the Bugti hills, as far east as the neighbourhood of Gandahári hill, some 20 miles east of Dera Bugti. North of this hill, however, a remarkable series of sandstones, with subordinate beds of conglomerate and clay, 700 feet or more in thickness, is seen resting upon the eocene shales and limestones with perfect conformity. The most conspicuous beds of the overlying formation are earthy brown (greyish brown) sandstones of great thickness, rather darker and harder than the Siwalik sandstones,[2] and with these brown sandstones are

[1] In this case, the statement I made in the Manual of the Geology of India, page 504, that there is very little doubt that the Nari group is represented in the Punjab, because some of the characteristic species of nummulites have been brought from Punjab localities, must have been founded on a mistake. I certainly, on one occasion, saw specimens which I identified with *N. garansensis*, and I think *N. sublævigata* also, in the Geological Survey Museum at Calcutta, and these specimens were said to have been brought from the Northern Punjab, I think from the neighbourhood of Murree, but I have not been able to re-discover them, and there may have been some error in the locality or identification.

[2] Whilst engaged in correcting the proofs of this memoir for the press, I have received Mr. Lydekker's "Geology of the Káshmir and Chamba territories; Mem. G. S. I., Vol. XXII. In this the tertiary rocks of the Pir Panjál are divided (p. 47), in descending order, into Outer Siwaliks, Inner Siwaliks, Murree group and Subáthu group. So far as the number of groups is concerned, this coincides with the classification of the Sulemán-tertiaries adopted in the present memoir, *viz.*, Upper Siwalik, Lower Siwalik, Nari beds, and Eocene. But the most important point is that the description of the Murree sandstones (p. 88) agrees singularly well with that of the Nari sandstones. Both have a considerable resemblance to those of the Siwaliks, but are distinguished by being harder and darker. The limits of the Murree beds have hitherto been somewhat indefinite, owing to the difficulty of distinguishing higher and lower strata of somewhat similar character, but if the harder and darker sandstones above the Eocene can be recognised as a distinct group, both on the Pir Panjál, east of the Jhelum, and on the Sulemán, west of the Indus, there appears good reason for believing that the same group of beds may be traced without difficulty across the Punjab.

associated, especially towards the base, dark reddish-brown sandstones, and reddish and yellowish-brown clays, some bands stained red by iron, and others black, apparently by manganese. One argillaceous sandy bed of a dark green tint mottled with red has a singular superficial resemblance to a volcanic rock.

Precisely similar beds occur throughout the hills to the east of the Sulemán, underlying the Siwaliks (or Manchhar), and resting upon eocene strata. There can be very little doubt that these beds are identical with the Upper Nari in Sind, although, in the Sulemán range, neither the oligocene limestone is to be seen at the base, nor the marine Gáj beds overlying. Despite the absence of these two important stages, no unconformity whatever, though carefully searched for, could be detected between the Nari beds and the strata above and below them.

Absence of marine miocene beds.

The complete absence of any representatives of the Gáj,[1] the great miocene group of Sind, throughout the area examined, is a great drawback in endeavouring to trace the distinctions of the different stages above the eocene system. Still no difficulty has been found in distinguishing, throughout the eastern flank of the Sulemán range, as far north as the survey was carried, three groups, composed chiefly of sandstone or conglomerate, conformable to each other and very rarely and exceptionally fossiliferous. These groups are the upper Nari just described and the upper and lower Manchhars or Siwaliks.

Lower Siwaliks.

4. Siwalik or Manchhar.—The rocks to which, in order to avoid any risk of introducing confusion into the terminology, the name of Manchhar was given in Sind, may, now that they have been traced so far to the northward, be identified without hesitation as Siwalik, and the latter name, which is older and far better known, may be

Identity of Siwaliks and Manchhars.

The separation of this group would go far towards completing the classification of the Punjab tertiaries, for the age of the Nari beds is well established by their position between two marine groups in Sind.

[1] Unless, as is possible, the lowest Siwalik beds, those containing vertebrate bones and the fresh-water mollusca subsequently noticed, represent the Gáj of Sind.

used for them. It must, however, be borne in mind that the mammalian and reptilian fossils found in Sind and the neighbouring countries came from the bottom of the system, whilst those of the Jumna and the base of the Himalayas generally are from near the top, and that the former belong to a far older fauna than the latter, the former being probably miocene, the latter pliocene.

Lower Siwalik of Bugti and Sulemán hills.

4 (*a*) *Lower Siwalik.*—The Lower Siwaliks of the Bugti hills and Sulemán range consist principally of the characteristic grey sandstone, a soft rock, moderately fine-grained, and owing its grey colour to small grains of a black mineral (probably hornblende) interspersed amongst the whitish quartz (or quartz and felspar) grains. With this grey sandstone are interstratified numerous bands of a peculiar conglomeratic rock, consisting of nodules or fragments of clay and soft sandstone, usually rolled, imbedded in an argillaceous or occasionally a sandy matrix. No pebbles of harder rocks occur. All the fragments appear to be derived from formations precisely similar in colour and mineral character to those associated with the conglomeratic or pseudo-conglomeratic beds themselves. Beds of clay often occur in this subdivision, and they are not unfrequently of a red (usually Indian red) colour; occasionally they are broken up, and the separate portions, sometimes a foot or two in diameter, rolled and re-deposited in a matrix of sand or clay of a different colour. Highly ferruginous bands, not uncommonly consisting of pseudo-conglomeratic beds strongly impregnated with iron, are found near the base of the group, and richly coloured clays and sands of varying tints are often seen in the same position.

Mammalian and reptilian remains.

In the lower beds of this subdivision fragments of mammalian and reptilian bones occur locally in considerable numbers. It israre for the bones to be perfect, but still occasionally unbroken specimens are found, and in one instance the greater portion, if not the whole, of a *Rhinoceros* skeleton, appears to have been imbedded. Several forms have been determined by Mr. Lydekker from beds in the same relative position in Sind, and from others supposed to

belong to this horizon in the north-western Punjab. It has already been mentioned in the introductory chapter that bones were noticed in these rocks near Dera Bugti by Captain Vicary, and several localities, especially Gandoi, Kumbi, and a spot 5 or 6 miles south-east of Dera, are prolific in remains of *Vertebrata* and also of mollusca. Of the former, *Mastodon* and *Rhinoceros* are the mammalia most frequently represented. Some teeth of *Dinotherium* have been obtained, and molars of an *Anthracotherium* and of a huge *Hyopotamus*.[1] Several teeth and bones await further examination. Bones of crocodiles, garials, and tortoises of various kinds are also found in considerable quantities. But the most important discovery was that of the following seven or eight species of fresh-water shells. They are described and figured in the appendix to this report.

Melania pseudepiscopalis, sp. nov.
M. gradata, sp. nov. 2 vars.
Paludina bugtica, sp. nov.
Unio vicaryi, sp. nov.
U. cardiiformis,[2] sp. nov., 2 vars.
U. cardita, sp. nov.
U. pugiunculus, sp. nov.

As will be seen by the above list, all of the seven species, sufficiently well preserved to be compared, are extinct and hitherto undescribed; one, however, *Melania pseudepiscopalis*, is closely allied to several living forms, and another, *Unio pugiunculus*, is less nearly related to some existing species. In both cases the surviving representatives are found in countries at a distance to the eastward. *Paludina bugtica* is not a characteristic type, but it is not near any living Indian form of the genus. All the other species are very different from anything now known to exist in any part of the globe.

[1] Since the above was written, some of these have been described by Mr. Lydekker (Pal. Ind. Ser. X, Vol. 2, Pt. 5, pp. 152, 158, &c.) as *Anthracotherium hyopotamoide* and *Hyopotamus giganteus*. The *Mastodon* found has been identified with the European *M. angustidens* (Rec. G. S. I., Vol. XVI, p. 161). The *Rhinoceros*, I learn from Mr. Lydekker, may perhaps be new, but it requires further comparison.

[2] It is probable that the ill-preserved ribbed bivalve mollusca found by Mr. Wynne in the beds overlying the eocene of Kohát, Mem. G. S. I., Vol. XI, p. 168, may have bee o e of the Unios now described.

All the above are typically fresh-water, probably river,[1] forms. They are associated with bones and teeth of rhinoceros. In the Sulemán hills, at the same horizon, close to the base of the Siwalik system, a few ill-preserved remains of mollusca were found in two localities. The majority appear to be fresh-water shells, and they comprise two forms of *Unio* closely resembling those obtained from the Bugti hills and probably identical, but with these Unios at one locality were a *Cerithium*, a *Natica* and a *Cyrena*-like shell, showing the presence of salt water. The bed in this case may have been of estuarine origin.

Relations to Upper Siwalik forms.

When it is remembered how close is the connexion between the Upper Siwalik mollusca of the Sub-Himalayan tract and those now living in the country,[2] and that, out of a considerable number of species found in Upper Siwalik strata, only one is supposed to be extinct or wanting in the recent fauna of Northern India, the circumstance that all or nearly all the forms from the Lower Siwaliks are extinct, and that none are even allied to the species of the same genera now inhabiting the country where they are found fossil, shows how wide a difference in age there must be between the two faunas, and renders it probable that a long period of time elapsed between the formation of the deposits in which they severally occur. The mammalian remains, as has already been shown,[3] led to the same conclusion, which is supported by the additional mammalian discoveries recently made.

Geographical distribution of Lower Siwaliks.

In the country recently examined, the Lower Siwaliks are found throughout the Sulemán range as far north as the survey extended, and throughout the southern

[1] All the Unios have thick heavy shells. This would prove but little alone, but the absence of any species with thin shells is opposed to the probability of the fauna having inhabited a marsh or lake. The absence of *Lymnæa*, *Physa*, *Planorbis*, and other lake and marsh-loving forms tends to the same conclusion. At the same time, the circumstance that in most of the specimens of *Unio* both valves occur united shows that the shells must have been preserved almost on the spot where they lived, and that they have not been washed any distance down a river.

[2] Manual of the Geology of India, p. 576, and Rec. G. S. I., Vol. XV, 1882, p. 106.

[3] Manual, pp. 472, 581, &c.

part of the Bugti hills. To the westward, however, the lower subdivision of the Siwalik system appears to die out, and although it may be represented on the west flank of the Bugti hills near Lehri, it entirely disappears further to the northward, for both on the Nári river and on the Bolán, Upper Siwalik beds rest directly, and in the latter case, unconformably, upon the eocene. The Lower Siwaliks appear always, in the Sulemán and Bugti hills, to be conformable to the rocks underlying them, whether these rocks belong to the Upper Nari group, as in the Sulemán range, or to the eocene, as in the Bugti hills. The perfect conformity in the latter case is very remarkable, for, at a distance of a few miles to the north-east, a mass of Nari sandstones and clays, little if at all less than a thousand feet in thickness, is intercalated, whilst at no great distance to the south-west, in Sind, several thousand feet of Gáj and Nari beds intervene. The sections in the Bugti hills are admirably adapted for exposing unconformity, if any exists; the boundary can be traced without a break, for 20 or 30 miles or even more, along barren cliffs and steep hill sides; and the Siwaliks, throughout this distance, rest upon a thin band of shaly limestone, underlain by soft shales and clays. The removal of the limestone at any place before the deposition of the Siwaliks would be easily detected, more especially as the soft underlying beds would in all probability have suffered from erosion. To complete the singularity of the case it must be remembered that not only is there a huge geological break between the two systems, a break represented by two whole groups of an aggregate thickness of 5,000 to 7,000 feet in a neighbouring country, but the lower or eocene system is purely marine, whilst the overlying Siwalik beds are entirely fresh-water or subaërial.

Relations to underlying beds.

4 (*b*) *Upper Siwalik.*—The Upper Siwaliks have a far more general distribution than any of the other tertiary groups above the eocene. They are perfectly conformable to the Lower Siwaliks, and indeed pass into them, yet the two are easily distinguished, as a rule, by the circumstance that the pseudo-conglomeratic beds, above described as consisting of clay or soft sandstone

Upper Siwalik.

nodules or fragments in an argillaceous or sandy matrix, are characteristic of the inferior sub-division, and are replaced in the upper group by true conglomerates of hard sandstone and limestone pebbles, in a sandy or calcareous matrix. Nummulitic limestone pebbles abound in the Upper Siwaliks of Baluchistan and the South-Western Punjab, but are not found in the lower, and the sandstones prevailing in the former are light-brown in colour, not grey as in the latter.[1] The sandstones of the Upper Siwalik do not differ greatly from those characteristic of the upper Nari beds, but the former are softer, paler in colour, and less earthy or greyish-brown.

Towards the top, as in Sind and elsewhere, the Upper Siwaliks become very conglomeratic, and the uppermost bed is usually an excessively coarse and massive conglomerate, generally abounding in rolled pebbles of nummulitic limestone. This conglomerate is frequently conspicuous from its forming a range of hills, sometimes of considerable height, at the verge of the hill area and on the edge of the alluvium. In one place near Choti Bálá, south of Sakhi Sarwar and south-west of Dera Ghází Khán, there is distinct unconformity between this uppermost conglomerate and the other beds of the Upper Siwaliks, but the unconformity is probably local and exceptional. As a rule, absolute conformity and transition prevail between all the subdivisions of the Siwalik system. At the same time, as has already been noticed, the Upper Siwalik beds overlap both the Lower Siwaliks and the Nari group, and rest upon the eocene beds in the hills surrounding the Kachi, and in the Bolán Pass there is great unconformity between the Siwalik and eocene beds, the bed resting upon the nummulitic limestone near Kohandiláni being apparently the uppermost Siwalik conglomerate.

Distribution on margin of Indus plain.

The Upper Siwaliks appear to form an unbroken fringe to the Indus alluvium from the south-western extremity of the area examined near Sibi to the neighbourhood of Dera Ghází Khán. Further north than the last named station, in some places at all events, the beds bordering the alluvial plain are apparently

[1] This distinction does not, I believe, hold good in the Sub-Himalayan tracts.

Lower Siwalik. The Upper Siwalik beds are, however, not confined to the margin of the hills, they occur in a long synclinal belt near the base of the Sulemán range north of Sakhi Sarwar, and similarly near Bugti Dera. They may perhaps also be found in the Mari hills. A conglomerate so closely resembling the uppermost Siwalik conglomerate as to be undistinguishable from it occurs around the Laláchi and Kirta plains on the Bolán route, and is also found, generally much disturbed and turned on end, in the valleys between Quetta and Kach on the Harnai route.[1] It should also be mentioned that Mr. Ball[2] observed similar conglomerate to the west of the Sulemán range. The circumstance that the Siwalik beds seen resting unconformably on nummulitic limestone in the Lower Bolán Pass, near Kohandiláni, are conglomerates of precisely similar character, tends to confirm the idea that the inclined conglomeratic beds around the Kirta and Laláchi plains and elsewhere in the neighbourhood belong to the same division of the Siwaliks.

Siwaliks near Quetta.

The occurrence of Siwalik conglomerate north-east of Quetta, on the road to Kach, has just been mentioned. West and north of Quetta other beds, chiefly clays and sandstones, that have every appearance of belonging to the Upper Siwaliks, recur in great thickness. They form the greater part of the Mashalak range, traversed by the Gháziaband Pass, and they appear to be extensively developed in Pishin. These beds have already been noticed in the introductory chapter, where reasons have been given for assigning them to the Upper Siwaliks, instead of to the Gáj, as supposed by Mr. Griesbach.

Fresh-water origin of Siwalik system.

It is scarcely necessary to recall the fact that nearly the whole Siwalik system on the north-eastern, northern, and western margins of the Indo-Gangetic plain consist of fresh-water or subaërial deposits. The few exceptions known

[1] I am informed that similar conglomerate occurs on Zarghun hill, over 11,000 feet high north-east of Quetta.

[2] Rec. G. S. I., Vol. 1874, VII, p. 150.

are local, and consist of beds, probably estuarine, at or near the base of the series, and at no excessive distance from the present coast, the most remote locality being the South-Western Punjab. By far the greater portion of the strata appear to have been deposited by rivers. The conglomerates of the Upper Siwaliks are evidently due to stream action, and the clays and sands, together with the conglomeratic beds or agglomerates containing pellets of clay and soft sandstone, have all the appearance of river deposits. Indeed many of the beds are very similar in character to those forming the great Indo-Gangetic plain; the gravels of the *bhábar* corresponding to the Siwalik conglomerates. It is true that the pebbles in the recent gravel slopes west of the Indus are more frequently subangular and less generally rounded than those of the Siwaliks, but in the tract at the base of the Himalayas, where the rainfall is so much heavier, the rounding of the pebbles is much more complete.[1]

Former extension of Indo-Gangetic plain.

The occurrence of the Siwaliks within the outer Afghan and Baluch hills at a considerable elevation above the sea may probably indicate that the great river plain of Northern India extended further to the westward and north-westward in Siwalik times than it now does, whilst the absolute conformity of Siwalik to eocene strata in so many places shows that in those places, at all events, the nummulitic rocks had been neither up-heaved nor disturbed till after the deposition of the Siwalik system. In other parts, however, as in the Bolán, the eocene beds had been disturbed, at all events before the formation of the Upper Siwaliks. The general evidence, nevertheless, on the margin of the South-Western Punjab, as in Sind, is that the disturbance of all the beds from the cretaceous upwards is mainly post-pliocene. In this respect there would appear to be a difference from the conditions described by Mr. Medlicott[2] as existing in the Sub-Himalayan tract, and this difference may indicate that the dis-

[1] This at least is the case so far as my observation has extended, but it would be well if some additional attention were devoted to the subject.

[2] Manual of the Geology of India, p. 570, &c.

turbance of the Himalayas preceded that of the north and south ranges west of the Indus.[1]

Post-pliocene and re-cent beds.

Post-pliocene and Recent.—If all the disturbed beds of conglomerate on the Bolán and Harnai routes and around Quetta be referred, as just suggested, to the Siwalik system, only the deposits of the various plains within the hills, and the slopes of gravel along the foot of each range, will remain to be considered as of post-pliocene age, together with the Indus valley alluvium.

Indus alluvium.

All these formations or deposits corresponding to them have been fully described and discussed already.[2] The plain of the Indus is covered by deposits from the flood waters of the river, mixed with fine dust and sand transported by the wind. In many places large tracts are covered with hillocks of blown sand, the abundance of this form of surface being always in approximately inverse proportion to the rainfall, for heavy rain tends to carry all such loose formations into the streams and thence to the sea. Along the edge of the hills is a slope of rounded or subangular gravel derived from the ranges. Where streams issue from the hill country, the gravels of the slope are more developed than elsewhere, and form the well known fan-shaped deposits. Generally to the west of the Indus the slope extends for a mile or two from theout ermost ranges; occasionally, however, the breadth is greater. Far beyond the marginal slope, the surface deposits are mainly composed of finer detritus brought down by the hill streams and spread by them far and wide over the surface of the plain. The "pat" or desert of the Sind frontier is mostly covered with silt derived from the hill ranges.

Gravel slope or Bhá-bar.

[1] In Sind also the principal disturbance appears to have been post-pliocene; Manual of the Geology of India, p. 474.

[2] Manual of the Geology of India, pp. 391, 421, 473, &c. Q. J. G. S., 1873, p. 496. Eastern Persia, Vol. II, p. 465. See also Drew, Q. J G. S., 1873, p. 445, v. Richtofen, China, I. pp. 56, &c. Tietze Jahrb. k.k. Geol. Reichsanst. 1877, p. 341, 1878, p. 581. Griesbach. Mem. G. S., Vol. I. XVIII, p. 9, &c.

The great gravel deposit of the Khirthar and Sulemán ranges not only forms a slope along the margin of the plain country, but it frequently occupies large areas within the outer ranges. In these instances an opportunity is afforded of seeing the process by which the great gravel slopes that fringe the plains of Central Asia have been formed, before the minor ridges have been covered up by the detritus derived from the higher.

The pebbles composing the gravel of these deposits are partly subangular, partly rolled. It is not always clear why some pebbles apparently derived from the same rock are much more rolled than others. The difference does not depend upon size. Some large boulders are rounded and some small fragments angular.

On the plains within the hills the surface formations vary greatly.

Post-pliocene beds of hills.

Sometimes, as on the Sham plain, the thickness of these accumulations is inconsiderable, and the underlying beds are exposed over a large portion of the area. Elsewhere, as near Quetta, the whole surface of the plain consists of subrecent deposits of great thickness, partly of aqueous origin, and washed by streams or floods from the hills around, partly in all probability, as in the Indus valley, derived from the atmosphere and consisting of fine particles transported by the wind. The latter form prevails towards the middle of the plains, whilst along the margins coarser detritus is deposited from water, so as to form the slopes of rounded and subangular gravel noticed by so many travellers, not merely in Afghanistan, but throughout the greater part of Central Asia. In the gravels of the slopes the underground channels known by the name of *Karez* in Afghanistan (and I believe throughout the Turk or Turcoman countries), and by the term *Kanát,* in Persia, are dug for the purposes of obtaining water for irrigation.

PART II.—DETAILS.

CHAPTER IV.

NOTES ON THE ROUTE FROM SIBI TO QUETTA BY THE BOLAN PASS.[1]

Alluvial plain near Sibi.

The greater part of the alluvial plain near Sibi resembles the "pat" or Sind desert which is near the base of the hills and owes its formation to deposits from the hill streams. There are, however, near Sibi, a few hillocks covered with pebbles, chiefly of nummulitic limestone. One or two similar hillocks covered with pebbles occur about 8 miles further south, near Pirak Pir (the tomb of a *pir*, or Mussulman saint, on one of the rises), and others towards Bráhim Barán, south-west of the road from Sibi to Pir Choki at the entrance of the Bolán Pass. The pebbles may be derived from a post-pliocene conglomerate, but as, beneath similar pebbles, both to the south-west near Dádar and south-east near Mal, Siwaliks appear, there can be very little doubt that the sandy clay of all these small hillocks is decomposed Siwalik sandstone and other beds, and the pebbles may be derived from Siwalik conglomerates.

Hillocks of Siwalik.

Hills between Dádar and Mittri.

South-east of Dádar and Pir Choki these hillocks rise into low hills, and form a tract of broken country extending for many miles from north-east to south-west. The low hills are crossed on the road between Mittri and Dádar, and have been noticed by many observers, from Hutton to Griesbach. They have especially been mentioned in the preceding introductory chapter, on account of the rocks composing them having been referred by the last named writer to the Gáj group. I crossed these hills from Pir Choki

[1] Many of these notes on the Bolán Pass are identical with those published by other observers, but they are here given as a whole to prevent the necessity for searching through numerous works for a description of the geology. Many of the observations, too, are, if not new, at least connected with a classification of the geological formations differing somewhat from that adopted in other descriptions of the route.

to near Mittri. They are composed of light brown or drab sandstones and clays with a few beds of gravel or soft conglomerate. A little gypsum occurs in flakes. I saw no red or white clays.[1] The hills are formed by a low anticlinal, and the beds dip west-north-west near Dádar and east-south-east on the Mittri side. The dip rarely exceeds 5°, and not more than 1,000 feet of beds can be exposed on the road traversed.

The beds are Upper Siwalik.

The beds are clearly, so far as I can judge, Manchhar or Siwalik, and I think all seen by me must be classed in the Upper Siwalik subdivision, as already stated in the introductory chapter. No Lower Siwaliks were detected in the neighbourhood, and no characteristic Lower Siwalik rocks, such as the grey sandstone, or the conglomerate of clay nodules, were found amongst the beds of the Dádar hills.

Relations of Siwaliks in Dádar hills to those of Pir Choki.

Dádar is on the alluvial plain that intervenes between the hills just noticed to the south-east and the outer ridges of the main range to the north-west. The Bolán Pass leading into the latter is entered at Pir Choki. Here the beds are Upper Siwaliks dipping north-west, and if the same dip is continuous beneath the alluvium around Dádar, the strata composing the hills to the south-east of Dádar must be at a considerably lower horizon. But, a few miles north of Pir Choki, the Siwaliks at the edge of the main range are seen to dip south-east, and there is much probability that they do the same beneath the alluvial plain between Pir Choki and Dádar, in which case the beds of the Dadár hills may be merely a repetition of those to the westward.

Siwaliks of Pir Choki.

The Siwaliks seen at Pir Choki consist of drab clays and sandstones, with some bands of conglomerate. All appear to be Upper Siwalik. The dip is about 10° to 15° to west-north-west. For about 3 miles the road, following the Bolán river, has a north-west direction, then there is a sharp turn to

[1] Some were noticed by Griesbach on the road he traversed, which lies 4 miles north of that examined by me. The beds seen on the two roads must be nearly on the same horizon.

the south-west. Just at the bend in the river, coarse conglomerate comes in, resting upon the sandstones and clays, and continues for about 6 miles to Kohandiláni, the road throughout running nearly parallel to the strike of the beds, which, however, dip rather irregularly. At Kohandiláni there is another abrupt change in the direction of the stream, and the road turns due north. The conglomerate continues for about half a mile, and then nummulitic limestone crops out from beneath it, apparently quite unconformably. The conglomerate is massive, neither sandstone nor clay being interstratified in general; it contains large pebbles of nummulitic limestone in abundance, and it has every appearance of being the uppermost conglomerate of the Siwalik system.

Conglomerate.

From half a mile above Kohandiláni the road traverses a narrow gorge in the nummulitic limestone till near South Kirta. The limestone at first is very nodular,[1] subsequently more distinctly bedded. The dip is irregular, but lower bed gradually appear, and before reaching South Kirta, sandy clays, light brown and olive grey in colour, crop out from beneath the limestone. These clays, as Mr. Griesbach has shown, are doubtless representatives of the beds at Mach, higher up on the Bolán route.

Nummulitics of Lower Bolán.

At South Kirta the gorge, through which the route has passed from Kohandiláni, terminates, and the road enters upon a large plain, covered with coarse gravel. This plain, called Laláchi to the north and Kirta to the south, on the map, extends about 25 miles from north to south, and is, where broadest, 6 miles wide. The gravel appears to have been entirely deposited by streams running from the surrounding hills, and is rather coarse in general, many of the fragments composing it being subangular, and a very large proportion of them consisting of nummulitic limestone. The surface of the plain is not absolutely level; there is a considerable ascent from south to north, and large fan-shaped deposits of coarse pebbles

Plain of Kirta and Laláchi.

[1] Griesbach, p. 80, suggests the possibility of this limestone being Nari. This, however, is not the case. Similar beds are not uncommon in the Khirthar of Sind.

occur at points where streams issue from the hills. One of the best marked of these is at Bibi Náni, the halting place beyond South Kirta. From the camp at Bibi Náni the road, instead of ascending as usual, descends over a distinct slope for some distance till the edge of the fan is reached, thence there is again an ascent. But no stream bed occurs at the bottom of the depression; the water of the stream to which the fan is due runs nearly at the top of the incline and supplies the Bibi Náni camp with water.

Fan deposit at Bibi Náni.

The hills around the plain are chiefly composed of nummulitic limestone, but at their base, throughout a great portion of the circumference, are low hills or hillocks of conglomerate, evidently of greater antiquity than the gravels of the plain, for the beds are inclined instead of being horizontal. Close to South Kirta, about 200 or 300 yards south of the camp, some small hills of this conglomerate consist of beds dipping 25° or 30° to the westward. The conglomerate is darker in colour than the gravels of the plain, in consequence of the large proportion of dark grey limestone pebbles, perhaps derived from cretaceous beds, that it contains. All the pebbles are thoroughly rounded, and some of them are of large size, some pieces of the dark grey limestone being a foot in diameter. Altogether the resemblance of this conglomerate to that of Siwalik age seen resting unconformably on nummulitic limestone near Kohandiláni is so great that the two are probably identical. As will be shown hereafter a similar conglomerate is very conspicuous on the Harnai route north-east of Quetta.

Siwalik conglomerate around plain.

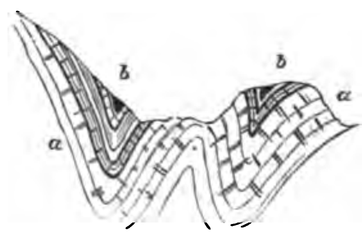
On the hills north-west of the camp of Bibi Náni (the range north of the spot called Bibi Náni on the map), a brown rock rests upon the nummulitic limestone, and, on account of the colour, is conspicuous from a distance. This brown rock proves, on examination, as already mentioned in the introductory chapter, to be the typical oligocene limestone of the Nari group,[1] precisely the same

Nari oligocene limestone near Bibi Náni.

[1] I am not at all surprised at Griesbach's not having noticed this bed. My own recognition of it was partly accidental; had I been marching from the north instead of from the

as in Sind, and abounding in the characteristic *Foraminifera; Nummulites garansensis, N. sublævigata*, and *Orbitoides papyraceus*. On the eastern side of the range, seen from the road, the Nari beds only appear in patches, and near the crest of the hills; but they line a small valley running nearly north and south between two parallel ranges, the more eastern of which is on the border of the plain. Besides the brown limestone, on the west of the small valley, there are some highly coloured variegated beds, purple, red, and white, probably also belonging to the Nari group. The brown Nari limestone is vertical, and has the appearance of being let in by synclinal folds, as in the following figure:—

W.



E.

Sketch section near Bibi Náni; *a* Eocene, *b* Oligocene.

Hills near Ab-i-gúm.

The ridge of hills on which Nari beds are exposed continues to Ab-i-gúm.[1] North of this place is a range of hills that looks from the road like a continuation of that to the south, and on this northern range there are also conspicuous brown limestones, but, on examination, where the hills approach the road, these beds appear to be below instead of above the main mass of nummulitic limestone, and to contain none of the characteristic oligocene foraminifera. Either there must be a fault at Ab-i-gúm, or the beds are much twisted and contorted.

The road leaves the open plain and enters more broken ground, shortly

south, I should probably have supposed it to be the same as a brown limestone seen, a little further north, much nearer to the road, and of lower eocene age. Of course when traversing a country rapidly, rocks at a distance from the road are only visited when there is reason to suppose they present features of peculiar interest.

[1] Ab-i-gaum of the accompanying map.

before arriving at the post known as Mach,[1] a locality that has attracted notice on account of the occurrence of coal or lignite beds in the immediate neighbourhood.[2] The rocks near the camp at Mach are all lower in position than the main mass of nummulitic limestone, which comes in to the eastward, and which they underlie; they consist of grey and olive shales, weathering into clays at the surface, soft sandstones, thin bands of coal,[3] and a few calcareous beds containing marine, or perhaps estuarine, fossils in great abundance, but of few species. One of the coal beds,[4] opposite the camp at Mach, measures 30 inches in thickness at one spot, but it is extremely doubtful if the thickness is constant for more than a few yards. The seam dips at 50° to the northward, and several smaller seams occur above it at intervals of a few feet. The thinness of the seams, the high

Beds associated with coal near Mach.

[1] Close to the spot marked Bent on the map. The place marked C. G. (? camping ground) is probably that called Ab-i-gúm by some travellers, and lies a little north-east of Mach.

[2] For a description of the coal and of its value for economic purposes see Rec. G. S. I., 1882, Vol. XV, p. 149.

[3] Griesbach's section, *l. c.*, pages 24-26, gives a fair idea of these beds. He states that the coal is formed of seaweeds, but does not give his reasons for adopting this opinion. I did not observe any remains of plants sufficiently well preserved to afford a clue to the character of the vegetation now preserved as coal.

I may here remark that I am not disposed to agree with Griesbach's view, that the lateral movement or pressure to which the convolution of the Mach beds is due "must have acted from the south-east towards north-west." I am rather disposed to believe that the pressure came from the westward or north-westward. To the south-east in the Bugti hills, and still more towards Sukkur and Rohri in Sind, the rocks are but little disturbed, whilst in the opposite direction the disturbance is excessive, showing, I think, that the lateral movement was greatest in that direction. Moreover, all round the Indian Peninsula, the thrust has the appearance of being towards the peninsula, not away from it. See Manual of the Geology of India, Introduction, p. lviii; Suess, Entstehung der Alpen, pages 126-144. Another point too on which I feel some doubt is whether, as Griesbach thinks, "the clays may have been pushed over the harder underlying limestone." It is more probable, I would suggest, that the actual lateral movement has been the same in both, although the effects may be somewhat different in producing contortion.

[4] An analysis of this coal by Mr. F. R. Mallet, gave—

Water driven off at 230° Fahr.	10·9
Volatile matter exclusive of water	33·1
Fixed carbon	41·0
Ash	15·0
	100·0

dips, and the softness of the associated beds combine to render any attempt to work the coal on a large scale hopeless. A considerable quantity of useful fuel can doubtless be obtained, but no permanent supply for large works, unless thicker beds are found under more favourable conditions.

The best sections are seen in the tributary streams, especially in one that joins the main stream or Bolán just opposite the camp of Mach. This tributary is the Maki nadi of the quarter inch map.

Conglomerate near Mach.

In the main stream itself scarcely anything is seen except conglomerate, disturbed in places, for instance just above the camp, on the west bank of the stream, where the dip is 30° to the westward. There is, however, much difference between this conglomerate and that occurring along the edge of the plain to the southward and supposed to be of Siwalik age, for the pebbles in the Mach conglomerate are less rounded, and boulders occur, some of them 5 or 6 feet in diameter.

Road north-west of Mach.

Beyond Mach, as far as Sir-i-Bolán, a distance of about 6 miles, the road runs in a north-west direction near the river, over a plain of gravel that extends for some distance to the east and north-east. South-west of the river, at a little distance, is a range of hills, composed of rocks, chiefly limestone, underlying the beds of Mach, and apparently of cretaceous age. The olive and grey shales and their associates are seen at intervals in the main stream and to the westward for some distance, being in general nearly or quite vertical. At the base of the range to the westward, at the only spot examined, in a position intermediate between the eocene shales and the limestones of the hills, a bed of limestone breccia was seen, of the peculiar character noticed in Chapter III as characteristic of the basement beds of the eocene system, and consisting of dark angular limestone fragments in a rather paler grey limestone matrix, both matrix and included fragments containing *Nummulites*. A ferruginous brown band abounding in small *Nummulites* was also seen.

Basement beds of eocene

A good section of the rocks beneath the eocene, the same doubtless

as those forming the range first noticed, is exposed in the narrow stream bed of the Upper Bolán Pass, through which the road runs from Sir-i-Bolán to Dozán. One of the highest beds seen is a dark grey limestone abounding in small *Nummulites* and *Operculinæ*, and with peculiar forms, probably concretionary, but resembling sponges, weathering out on the surface. In another bed an *Orbitoides* occurs (probably *O. dispansus*, the common eocene species). No *Alveolinæ* were observed. These beds appear to be the lowest of the eocene system, and very nearly on the same horizon as the limestone breccia mentioned in the last paragraph. Beneath them is a considerable thickness of dark grey or black limestone, traversed for some distance by the stream, which runs at this spot, the narrowest part of the pass, nearly parallel with the strike of the beds. Towards the base of the limestone is a bed containing large concretions of flint a foot in diameter, and below this bed there is some pisolitic iron ore. Then comes sandy limestone containing rounded grains of silica, and then a great thickness of cream-coloured thin-bedded shaly limestones or limestone shales, in which no fossils could be found. The thickness of the whole, beneath the beds believed to represent the base of the eocene, may perhaps be 500 feet or rather more. The cream-coloured shaly beds are the "variegated limestone shales," and the more massive dark overlying rock the "black compact limestone" of Chapter III.

Upper Bolán Pass.

Opposite the camp at Dozán there is a cliff of the limestones seen in the stream section. At the base are the whitish and grey shaly limestones, having a thickness of probably 200 feet.

Dozán.

From Dozán the road runs west for 2 or 3 miles, passing first over the same limestone shales, and then turns to the south-west at a spot where the strata are much disturbed. Beneath the limestone shales, thick black or blackish limestone, veined with white calcspar, crops out. This rock is clearly the same as the upper portion of the thick cretaceous limestone near Quetta. After 2 or 3 more miles, the road again turns to the north-west, crosses a low ridge of the

blackish limestone, and enters on the Chota Dasht of the map, one of the plains of the Quetta plateau.

Chota Dasht and Dasht-i-Bedaolat.

The "Chota Dasht" and Dasht-i-Bedaolat[1] are broad flat plains, absolutely stoneless in general, although the latter is covered with stones to the northward near Sir-i-áb. They are very barren from want of water, but consist of a fine soil, probably of subaërial origin, and that would doubtless be highly fertile if irrigated.

Road from Darwáza to Quetta.

The road to Quetta from the point where the Chota Dasht is entered runs first north-west, and then nearly north across the plain. The hills north and south of the comparatively narrow strait called Darwáza, (where there is a camping ground called Dasht,) that unites the two plains, consist of the black cretaceous limestone dipping west by north. The hills immediately east of the road, 6 or 7 miles beyond Darwáza, are of the same limestone, upon which, close to the road, white, cream-coloured and purplish shaly limestones rest, overlain by more black limestone, interstratified with some that is brown and some whitish in colour. All dip to the south-west, in the direction of the plain, and no higher beds are seen. There can be no reasonable doubt that the variegated shaly limestones are the same as the beds of Dozán, and in each case, as in the Chehiltan range to the westward, black limestone overlies them. The thickness of the two above the thick black limestone of the hills north-west of Darwáza is probably about 500 feet. Eocene beds should come in above the upper black limestone, and they probably do so beneath the deposits of the Dasht-i-Bedaolat. The same thick black cretaceous limestone appears to continue throughout the hills on the east of the flat as far as Quetta.

Uppermost cretaceous beds north-west of Darwáza.

Hills south of Quetta.

The hills west of the road to Quetta a little south of Sir-i-áb are an anticlinal of pale cream-coloured limestone, very homogeneous in texture, and precisely simi-

[1] Little flat and Poverty flat. The latter is a much closer equivalent for *Dasht-i-Bedaolat* than Sir R. Temple's translation "Vale of Poverty."

lar to the hippuritic limestone of Persia. These beds must underlie the thick black limestone, which comes in again to the westward, and forms the Chehiltan range, on which some notes will be found in the next chapter.

CHAPTER V.

NOTES ON THE NEIGHBOURHOOD OF QUETTA.

Position of Quetta.

The town of Quetta stands in a comparatively fertile plain, drained by the tributaries of the Lora river. As usual in all Central Asiatic plains, the margins are stony and formed of a slope of detritus washed from the neighbouring hills. Quetta stands at the base of the slope forming the eastern margin of the plain.[1]

Peat.

Some peat[2] occurs about half a mile west of the station at Quetta, and occupies a considerable area of marshy ground. The peat is not very pure, as it is somewhat mixed with earth, but it closely resembles that found in Europe. None was traced in process of formation.

Miri or citadel.

The Miri or citadel of Quetta is on the top of a mound, rising 50 or 60 feet above the plain. A gallery driven by the military engineers through this mound, near the

[1] Griesbach (*l. c.*, p. 38) describes the valley of Quetta as "a trough formed by the natural flexure of the cretaceous limestone beds." He adds: "The basin so produced is now filled with alluvial deposits, but this of course does not interfere with the collection of water, which gradually fills the basin and may now be found within a few feet of the surface soil." I doubt if this explanation is quite correct. I suspect that part of the valley is underlain by eocene beds, resting upon the cretaceous, and it seems to me possible at least that the occurrence of water close to the surface (some issues in the form of springs) at Quetta itself may be due to the circumstance that some of the alluvial deposits do interfere with percolation. The water is probably derived from the gravel slope to the eastward, and may be brought to the surface, because it is prevented from descending further by impermeable beds in the deposits of the plain, and not because it is contained in a basin of so permeable a rock as limestone. With reference to this question, it should be remembered that in Griesbach's figures, page 37, the heights are on a very much larger scale than the horizontal distances, the former being proportionally about ten times as great as the latter.

[2] This peat was shown to me by Dr. Fullarton, Residency Surgeon.

base, shows that the whole hillock is of artificial origin, for fragments of pottery and bones of domestic animals are found throughout. Some other hillocks of similar form, but smaller size, in the neighbouring plain are also probably artificial, and formed by the remains of buildings.

Localities visited near Quetta.

Time only allowed of a visit to three localities in the neighbourhood of Quetta. These were—(1) the Gháziaband Pass across the Mashalak range, 12 to 14 miles north-west of Quetta; (2) the northern portion of the Chehiltan range, about 4 miles west of Quetta; and (3) the base of the Takátu range, north of the town.[1]

Gháziaband Pass.

1. The Gháziaband Pass is on the road from Quetta to Kándahár. Ascending from Mehtarzái on the Quetta or eastern side of the range, the first inclined bed seen is a gravel, dipping at 5° to the eastward, and containing numerous subangular blocks of black limestone. Beneath this bed, which may possibly be of post-pliocene age, are Siwalik sandstones, usually light brown, and clays, drab, light brown, Indian red or greenish-white in colour. Some conglomeratic bands also occur, and gypsum is interspersed throughout the beds. It usually occurs in flakes with a fibrous structure, filling cracks in the sandstone and clays,[2] and a considerable quantity is procured from this neighbourhood for building purposes. Further down in the section, the clays are less abundant and the sandstones very conglomeratic, the pebbles being occasionally subangular. Many of the pebbles are of limestone, sometimes with nummulites. As already pointed out in Chapters I and III, there appear good reasons for classing all these beds as Upper Siwalik.

Siwaliks.

Towards the western side of the pass eocene beds appear. They consist of vertical[3] shales and limestone, striking north-north-east to

[1] Several details concerning the sections seen at these localities have already been given in Part I, Chapters I and III. In the former the main points are mentioned, in which I differ from Griesbach's interpretation of the geology.

[2] Griesbach mentions its occurrence also in beds and lenticular masses.

[3] In Griesbach's section (*l. c.*, p. 19) they are represented as nearly horizontal. This section may perhaps not be taken from the road, although, from the description, I should

south-south-west. The shales vary in colour, grey or olive predominating; some are reddish, others light brown, and there is a great variety of tints. The limestone is black, abounding in *Nummulites*, amongst which are *N. spira*, *N. obtusa*, and other species. An *Alveolina* also occurs. All the beds are much hardened, and the shales have polished surfaces and an ancient appearance, almost like slate in some places.

Eocene beds.

2. The beds of the Chehiltán range, which forms the western boundary of the plain south of Quetta, have already received a large amount of notice in Chapter III, and incidentally, in the discussion of Mr. Griesbach's observations, in Chapter I.

Chehiltán range.

At the northern extremity of the range there is a rather broad fringe of Siwalik beds.[1] These consist of sandstones, clays, and conglomerates, precisely similar to the beds of the Gháziaband Pass. The pebbles in the conglomerate are very angular.

The Siwaliks rest quite unconformably on cretaceous and eocene beds. The latter are intermediate in character between those of Takátu, where massive limestone of great thickness overlies thick shales, and those of Gháziaband. The limestones are very flaggy, and much interstratified with shale. There is a great thickness of these interstratifications resting upon a thick belt of shale. The shale is not so much hardened, as it is 6 miles further west in the Gháziaband Pass.

The eocene beds overlie cretaceous rocks; the general dip is to the westward, and the latter form for a long distance a detached ridge bordering the Quetta plain. A peculiarly good section of the uppermost cretaceous beds is seen in the gap cut by a small stream which runs out into the Quetta plain just north of the village of Karani. This is the section described and figured by Mr. Griesbach.[2] The following notes

have supposed this to be the case. The disturbance of the eocene beds in general in this neighbourhood is, however, greater than is represented in the figure, and the dips are higher.

[1] Their occurrence was recorded by Griesbach, who looked upon them as Gáj.

[2] *L. c.*, p. 35, fig. 7, p. 37, and Plate IV, Profile 1.

take necessarily more or less the form of a commentary on his description. The rocks are described in ascending order.[1]

Section near Karani.

Cretaceous 3. 2 (1).—The lowest rock seen is the thick blackish limestone extending all along the base of the range, and identical with that forming the hills east of the plain from Darwáza to Quetta, and that crossed in the Upper Bolán between Dozán and Darwáza.

Cretaceous 2. 3 (2, 3, 4 and 5).—These, the variegated limestone shales, are a well-marked assemblage of calcareous shales and shaly limestones, chiefly white or cream-coloured, but variegated with purplish red. These beds appear to be at least 500 feet thick, and are apparently identical with those mentioned in the last chapter as being seen 6 miles north-west of Darwáza, and with those of Dozán in the Upper Bolán Pass. As will be shown hereafter, similar beds occur near Kach, north-east of Quetta.

Cretaceous 1. 4 (6).—Above the variegated limestone shales is a black, hard, compact limestone about 150 feet thick, and, from its hardness and dark colour, conspicuous at a distance, and forming a well-marked dark band[2] along the crest of the detached range of cretaceous rocks already mentioned. By Mr. Griesbach this bed is described as "black, hard dolomitic limestone of great thickness ...... filled with small *Ostrea.*" The thickness, however, is considerably less than that of the subdivisions immediately above and below, although the band itself considered as a single homogeneous bed is unusually thick. At the locality examined, the fossils occurring in this black limestone are not well marked, some may be oysters, some are small *Foraminifera*, but the rock, where I saw it, is not "filled with *Ostrea.*"

The little stream along which the section is seen has cut a narrow channel through the hard limestone band, and after traversing the small pass thus formed, which runs east and west, the path enters a compara-

[1] The Roman numerals refer;—the first, not in brackets, to Griesbach's section, p. 34, of his memoir, and figures 7 and 8, p. 37; those between brackets to the section on p. 35. The prefix in italics refers to the section in Chapter III of this memoir.

[2] As shown in Griesbach's Plate IV, Profile 1. The bed is there called *Ostrea* limestone.

tively broad north and south valley between the partially detached ridge of cretaceous beds and the main eocene range. This valley is entirely cut out of the lower eocene beds.

Lower Eocene, 5 (7).—The beds exposed in the valley are the usual olive shales of the eocene system. A few bands of grit, weathering of a brownish tint, are intercalated with the shales, which decompose at the surface into a soft argillaceous substance having a superficial resemblance in both colour and consistency to decomposed basalt. These shales dip at an angle of 45° or rather more. The whole breadth of the valley is at least one-third of a mile, probably, on an average, nearly or quite half a mile, and the thickness of the shales cannot be less than 1,300 feet, and may be 1,800 or more.[1]

Eocene, 6 (8, 9, 10, and 11).—Above the olive shales there is a great thickness of shaly and flaggy limestone, sometimes sandy, especially towards the base, and but rarely fossiliferous. These beds form the range west of the valley occupied by the lower eocene shales, the main range in fact. About 500 feet were cursorily examined, but there is a much greater thickness exposed, and there appears good reason to believe that the rock is the same as the nummulitic limestone of Takátu, and of the Bolán Pass, but more shaly and less fossiliferous.

South base of Takátu.

3. The great mass of Takátu, rising to a height of 11,375 feet above the sea and 5,570 above the Quetta plain, consists mainly of nummulitic limestone. At the base of the steep scarp, which forms the southern declivity of the mountain and the northern boundary of the Quetta plain, the soft olive eocene shales are well exposed. They are very thick, apparently considerably thicker than in the section of the Chehiltán range just described, and contain some sandy or gritty beds, a few bands of calcite, and occasional intercalations of impure limestone, one of which, of a brown colour, precisely resembles that at the base of the eocene system in the Bolán Pass, not only in

[1] It will thus be seen that Griesbach has under-estimated the importance of this subdivision, which, in his figs. 7 and 8, p. 37, is represented as inferior in thickness to the hard dark limestone beneath it. For further remarks on these shales see Chapter I of this memoir.

colour and structure, but in containing, in abundance, small *Nummulites* and *Operculinæ*. Under Takátu, however, the bed appears to be intercalated in the shales, not at the base of them.

The same shales, weathering into clay at the surface, continue all along the base of the range, from a point considerably west of a line drawn due north from Quetta, to the Sarakula valley, which they occupy exclusively. No cretaceous bed could be found north-west of the Harnai route.

CHAPTER VI.

NOTES ON THE ROUTE FROM QUETTA TO SIBI VIÂ HARNAI.

Sarakula valley, to south-east of Takatu.

The road from Quetta to Harnai runs for some miles north-east across the plain, and then enters the Sarakula valley, which is entirely composed of lower eocene olive shales, the continuation of those seen at the base of Takátu. With these shales are associated greenish sandstones, sometimes passing into coarse grit and even into conglomerate. The sandstone is usually soft, but some hard brown calcareous rock occurs that stands out from the soft shales. The more ordinary soft form weathers into a mammillated surface, like that of some Siwalik sandstone.

Limestone in shales.

Beds of limestone are also interstratified with the shale; one conspicuous vertical band, a few miles from the entrance to the valley, abounds in *Nummulites* of several species, comprising *N. granulosa*, *N. spira*, and a form allied to *N. brogniarti*, together with *Alveolina*, *Orbitoides*, and large *Orbitolites*, more than an inch in diameter.

Limestone of Takatu.

The nummulitic limestone of the great hill mass of Takátu, forming the north-western slope of the valley, overlies the shales, but, as is so commonly the case, where a hard massive formation rests upon soft, argillaceous beds, enormous

Slips.

blocks, even hills, of the limestone, appear to have slipped down upon the shales, so that the relations of the two are, in places, very difficult to understand, for the shales

are much contorted and frequently vertical. On the south-eastern side of the valley, near Gandak, the usual camping ground for travellers halting between Quetta and Kach, a thick band of limestone, intercalated in the shales, comes in dipping south-east, or in the reverse direction to the beds north-west of the valley. This limestone band, however, a little further to the south-east, turns up again and dips north-west, forming the high ridge over 9,000 feet high (*i.e.*, above the sea), called Nar on the map. The uppermost cretaceous beds probably come in on the opposite or south-east side of this ridge.

Ridges south-east of valley.

Some of the shales near Gandak are red instead of olive. Sandstone beds become more abundantly developed further up the valley; some of these sandstones being gritty and even conglomeratic. Amongst the coarser as amongst the finer beds all the material appeared to be sedimentary.

Sandstones.

In places, resting unconformably on the eocene beds, there are enormous masses of conglomerate, often turned up and dipping at high angles. Here and there this conglomerate appears to have filled the valley at one time. Hills formed of this rock, with the bedding nearly, if not quite vertical, are seen to the north of the spot where the road leaves the Quetta plain, and a ridge of considerable height, immediately west and south-west of the camping-ground at Gandak, consists of the same formation. This conglomerate is evidently of comparatively late origin; it abounds in nummulitic limestone pebbles, most of them well rolled, and it precisely resembles the uppermost Siwalik conglomerate, to which it probably belongs.[1]

Siwalik conglomerate.

The road beyond Gandak, after pursuing a north-east or north-north-east direction for several miles, turns abruptly to the south-east, and then to east. Just where the turn takes place, on a hill crossed by

[1] The same conglomerate, as already mentioned in Chapter III, is said to cap Zarghun mountain, a few miles to the south-east. My information is derived from Sir. O. B. St. John. The occurrence of conglomerate on Zarghun was observed by Captain Beavan of the Trigonometrical Survey.

the track, a thick bed of conglomerate appears, dipping 60° to 70° to the southward. This bed continues for a long distance towards Kach, south of the road.

Cretaceous limestone, shales, &c.

Soon after the change in the direction of the road, variegated limestone shales, apparently the same as the cretaceous beds of Dozán, the Chehiltan range, &c., crop out from beneath the olive eocene shales north of the road, and continue to Kach. Beneath the limestone shales dark limestone appears, and a peculiar blackish rock, apparently decomposed basalt, is associated with them.

Position and geology of Kach.

The fortified post of Kach is situated at the junction of several important routes traversing the valleys that meet at this spot. The village of Kach is between 2 and 3 miles distant to the north-east, and Amadun is 2 miles further in the same direction.

The Valley of Kach[1] is composed of the eocene olive shales, which in this direction, and indeed throughout the route from Quetta to Harnai appear gradually to increase in thickness. The great mass of hills to the eastward, part of the Pill range, is of nummulitic limestone, apparently overlying the shales. To the north-west of the Kach valley is a ridge, the continuation of the belt of cretaceous beds seen north of the road from Gandak, but this belt north of the fortified camp rises into a range of considerable height. It sinks again at Amadun, but rises again higher than before to the east of Amadun, and forms part at least of the Bibai range.

Section of cretaceous beds near Kach.

A path runs from the camp at Kach to the north-west across the cretaceous ridge, and further on joins the road to Gwál, in Pishin. The path crosses lower eocene

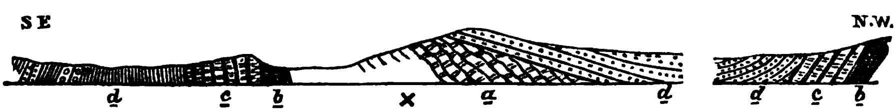
[1] Unfortunately fever on the road from Gandak to Kach, and whilst at Kach, seriously interfered with my power of making observations in that neighbourhood, and throughout the route as far as Harnai. This was particularly unfortunate, for the geology is very interesting, and not only was I prevented from visiting some localities that I might otherwise have seen, but my observations, even of the places examined, were imperfect. I was obliged to leave the question of the unconformity of the eocene beds upon the supposed cretaceous and the manner in which the thick limestone of Takátu and Zarghun appears to die out, and another great mass, lower in the system, to come in to the eastward, very imperfectly explained.

shales for some distance, and amongst them a conspicuous bed of conglomerate. The pebbles are much larger than usual, and consist of sandstone, grit, limestone and chert, many fragments of the latter being angular. No basalt, nor any other volcanic fragments, could be detected, and this is interesting, as marking the contrast to the conglomerate near Amadun to be noticed presently.

The olive shales and sandstones dip at first to the south or south-east; further to the north-west they become vertical, and are succeeded, apparently in regular descending order, by variegated limestone shales, white and purplish red in colour, and dipping north-west at a high angle. This is probably a reversed dip, and the limestone shales are much crushed. They look a little different from the limestone shales near Quetta, probably in consequence of the greater amount of disturbance, but there can be very little doubt of their being the same beds.

The next bed is not so well seen. It is a homogeneous rock, very dark coloured, apparently a decomposed basalt (anamesite). This is followed by nodular light grey limestones dipping north-west at a much lower angle, but somewhat contorted. Above these limestones, dipping at a still lower angle and quite unconformable to them, are dull greenish sandstones, precisely similar to those associated with the lower eocene shales, and almost certainly belonging to that group. To the north-west of the ridge, however, neither shales nor conglomerates were observed, although both occur to the south-east only a few hundred yards away.

Unconformable superposition of eocene on cretaceous rocks.



Sketch section showing unconformity between eocene and cretaceous beds near Kach: *a*, cretaceous limestone; *b*, basalt; *c*, variegated limestone shales; *d*, lower eocene; × probable anticlinal, perhaps faulted.

Proceeding to the north-west the path passes over a plain, on which the sandstones continue for a mile or two, dipping at low angles, then there is a synclinal curve, and a little further on the variegated lime-

stone shales crop out once more. Here, again, the eocene sandstones appear to be unconformable to the underlying beds. At this place true basalt is associated with the variegated limestone shales, whether it is interstratified or intrusive is not so clear, but the appearances are in favour of intrusion.

In the accompanying sketch an attempt has been made to represent this very interesting section; the sketch is copied from my note-book, and merely records what was seen, without attempting to explain it. If, as appears most probable, the sandy beds to the north-west of the cretaceous limestone ridge are the same as the shaly beds to the south-east, there is evidently a very sharp anticlinal of the underlying cretaceous rocks, probably complicated and rendered indistinct by faulting.

Ridge north-west of Kach valley.

As already remarked, the ridge of cretaceous rocks to the north-east of the section just described rises to a considerable altitude along the north-western side of the Kach valley, the variegated limestone shales continuing nearly vertical throughout. The crest of the range is formed by the nodular grey limestone, and between the two limestones basaltic rock is seen in places and may be continuous throughout.

Hills east of Amadun.

East of Amadun, this band of basaltic rock assumes large proportions and is conspicuous from a distance, forming a broad dark band on the hill side. The character, however, appears to be greatly changed. About 3 miles east-north-east of Kach village and 2 miles east of Amadun, the following is the section exposed. At the base of the olive shales there is the typical limestone breccia of the lowest eocene beds, dark angular limestone fragments in a rather paler calcareous matrix, as near Mach, in the Bolán, at several places in the Sulemán range, and elsewhere. Here the breccia contains *Alveolina* and other *Foraminifera*, but no *Nummulites* were observed. This bed is nearly or quite vertical. Then come the variegated lime-

Conglomerate of basaltic pebbles.

stone shales, and then the volcanic band, here consisting entirely of a coarse conglomerate. bles and matrix are both entirely derived from volcanic rocks; the

pebbles vary much in constitution—all appear to be doleritic, but some are ordinary basalt, some are prophyritic, many contain black crystals, apparently of pyroxene, others consist of anamesite. All are rolled thoroughly; the size varies, some being a foot in diameter, but the majority measure from 3 to 6 inches.

Limestone of Bibai range.

This conglomerate can scarcely be less than 1,000 feet in thickness and it may be more. The upper part of the hill consists of hard massive limestone, apparently resting on the conglomerate, but really, in all probability, inferior to it; the dips here, as near the Kach camp, being inverted. In the limestone are some obscure *Foraminifera*, but no *Nummulites* nor *Alveolina* could be detected. The limestone must be very thick; it forms all the upper portion of the Bibai range near Amadun.

These sections, it should be remembered, afford the first instance hitherto observed on the western frontier of India of unconformity between eocene and cretaceous beds.

Road eastward from Kach.

From Kach post the Harnai road runs east-south-east to Manji, along a valley composed of eocene olive shales, having, in general, a southerly dip, whilst the Pill range to the north is composed of nummulitic limestone.[1] This limestone, as already stated, appears to overlie the olive shales of the Kach valley, but towards Manji the massive limestones of the Pill range to the northward appear to dip under the shales of the valley and to rise again from beneath the latter to the southward, and to form the anticlinal hog-backed range traversed by the road at the Chappar rift. This rift, which is simply a gorge cut through the limestone range by the stream from Kach, has already been described, so far as the limited observations made when traversing it at night allowed, in Chapter II. The uppermost beds traversed are undoubtedly nummulitic, and so, probably, are all the rocks exposed in the gorge, but lower strata may be cut into.

Chappar rift.

[1] I was suffering from fever and obliged to travel in a doolie, so the observations on this portion of the route are of doubtful accuracy.

After traversing the Chappar rift the road runs from Dargi almost to Spintangi, a distance of nearly 50 miles, in an east-south-eastern direction parallel to the strike of the beds, and passes along a broad valley formed by the olive shales of the eocene and their associates. In this valley are the military stations of Sháhrág or Shárigh and Harnai. Although the valley is continuous throughout, all the streams draining it break through the hills to the southward, showing, as already noticed in Part I, Chapter II, that the course of the streams must be of greater antiquity than the present form of the surface.

Valley of Sháhrág and Harnai.

The range north of the valley, the continuation of that through which the Chappar rift runs, gradually rises to the eastward to a great height, amounting, north of Sháhrág, to 11,440 feet above the sea, according to the determinations of the Topographical Survey, and upwards of 7,000 feet above the Sháhrág plain. Immense limestone cliffs are seen in this range, and it is very probable that part of the rocks composing it are older than eocene. Further east, the range again sinks into a hog-backed ridge, apparently a simple anticlinal.

Range north of Sháhrág.

The range south of the valley consists of alternations of sandstone and shale with some beds of limestone. The general dip is south or south-west, but the angle, west of Sháhrág, is not high. The same, rather low, south-westerly dip is found in the valley, except near the northern range, where the angle of inclination is higher. The thickness of the beds exposed in the southern range (Bilen Pingi on the map) can scarcely be less than 2,000 feet, and probably as much more crops out in the valley itself.

Range south of valley.

At Sháhrág the plain is unusually broad from north to south, and is very much covered with sub-recent deposits of gravel, sand, and clay.

Sháhrág (or Shárigh) is the locality already noticed where the occurrence of coal has been reported.[1] The spot where this coal occurs is

[1] For a description of the economical value of the coal, see Rec. G. S. I., 1882, Vol. XV, p. 149.

about 3 miles south of the village and of the military station, on the feeders of a stream called the Siah Dad. A good section is seen in a small watercourse that joins the main stream from the right or western side just above the spot where the latter cuts its way through the hills to the southward. The beds are vertical or nearly so. The following measured section is in descending order, and commences to the south, close to the main stream.

Section of Coal-beds near Sháhrág.

	ft.	in.
1. Light greenish-grey calcareous sandstone	1	4
2. Impure grey sandstone, with fragments of shells	0	8
3. Olive-grey shale	5	0
4. Grey limestone	0	4
5. Light brown calcareous sandstone	2	2
6. Olive-grey sandstone	1	3
7. Sandstone, calcareous in parts	0	7
8. Soft olive-grey sandstone	1	9
9. Do. with a few obscure shales	1	2
10. Not seen (probably soft shale)	15	0
11. Olive-grey sandstone, some of it hard, containing in places nodules of fawn-coloured clay	4	8
12. Olive grey marl, abounding in *Ostrea, Cardita, Turritella*, and other shells	2	0
13. Bluish-grey shale, with some calcareous nodules in the upper portion	4	0
14. The same, with bands 3 inches to a foot thick, of rather calcareous sandstone	7	6
15. Grey shell marl, full of shells, *Turritella* and various bivalves (*Lamellibranchiata*) crushed and undistinguishable	0	10
16. Carbonaceous shale apparently pyritous (much decomposed)	0	6
17. Impure limestone with carbonaceous bands full of shells (undistinguishable)	0	2
18. Carbonaceous shales	1	0
19. Brown clay	0	2
20. Carbonaceous clay	0	4
21. Impure shaly limestone	0	3
22. *Coal*	0	3
23. Carbonaceous shell marl	0	5
24. Shale, more or less carbonaceous	2	2
25. Sandy shale, with hard nodular calcareous bands	2	0
26. Carbonaceous shale (decomposed), apparently containing much pyrites originally. (*N. B.*—In these beds all the pyrites have decomposed and are represented by a yellow deposit.)	1	9

	ft.	in.
27. Soft grey shale	1	9
28. Hard calcareous and nodular shale	0	10
29. Shale, sandy in parts, carbonaceous in others	5	0
30. Shell marl, carbonaceous	0	3
31. Olive-grey shale, rather carbonaceous in parts and containing a band of hard nodular limestone	20	0
32. Shell marl	0	2
33. Carbonaceous pyritous shale	0	4
34. *Coal*, about an inch good, the rest shaly	0	5
35. Carbonaceous pyritous shale	1	0
36. Red sandy clay, full of bivalve shells	0	1
37. *Coal*	0	4
38. Grey marl, abounding in *Ostrea* and other bivalves	0	3
39. Soft olive-grey shale, with harder marly beds abounding in shells	2	0
40. Shale, in part highly carbonaceous, with a thin band of nodular limestone	3	0
41.* Impure nodular limestone, sandy in part	3	0
42. Soft grey shale with some calcareous nodules	2	6
43. Shell marl	0	1
44. Soft grey shale	0	9
45. Impure nodular limestone	0	7
46. Shale, carbonaceous in parts	3	6
47. Impure nodular limestone	0	8
48. Shell marl passing into limestone	0	9
49. Carbonaceous shale and a little coal	0	3
50. Limestone full of shells	0	1
51. Shale, rather carbonaceous, with a thin band or two of coal	2	2
52. Coal and shale interstratified, very pyritous apparently	1	4
53. Soft grey shale, with nodular limestone bands and one or two very thin beds of shell marl	16	0
54. Sandy shale, with some impressions of stems of large plants	1	2
55. Nodular limestone, flaggy, with numerous bivalve shells, *Turritella*, &c., seen in section	1	4
56. Carbonaceous shale, with thin layers of coal	1	9
57. Shell marl passing into limestone	1	0
58. Shale, highly pyritous	5	0
59. *Coal*, mostly pure, but with one or two thin shale partings	0	10
60. Shale, very carbonaceous in parts	6	0
61. Shell marl	0	7
62. *Coal*	0	2
63. Carbonaceous shale, with one or two thin seams of coal	5	3
64. Impure limestone with some shells	0	4
65. *Coal*	0	1
66. Carbonaceous shale	0	1

	ft.	in.
67. *Coal*, good in general, a small portion earthy. (*N. B.*—This is one of the seams used for fuel, and of which a sample was taken for analysis.[1])	1	9
68. Sandy shale and sandstone	25	0
69. Shale, more or less carbonaceous, and some nodular limestone	5	0
70. *Coal*, mostly good	1	0
71. Shale	2	9
72. *Coal*	0	8
73. Shale	5	6
74. Impure *coal*	0	2
75. Carbonaceous shale	0	9
76. *Coal*	0	4
77. Shale	10	0
78. Shale and coal intermixed	1	0
79. Shale	3	6
80. Shell marl	0	3
81. Shale, containing nodular bands and one or two thin seams of *coal*	13	0
82. Shell marl	0	3
83. Coal	0	1
84. Shale	0	7
85. Nodular limestone	5	0
86. Shale, with thin layers of *coal*	21	0
87. *Coal*	0	8
88. Shale	5	0
89. Nodular limestone	1	0
90. Shale	14	0
91. Shell marl, with large bivalve shells	0	6
92. Carbonaceous shale	0	5
93. *Coal*	0	4
94. Shell marl	0	2
95. *Coal*	0	3
96. Shale	0	2
97. *Coal* and shale intermixed	1	1
98. Shale	0	8
99. *Coal*	0	10
100. Ferruginous clay and shell marl	0	2
101. *Coal*	0	7
102. Carbonaceous shale	0	9
103. Grey shale, with some nodular limestone	18	0
104. *Coal*	0	6

[1] Analysis by Mr. F. R. Mallet—

Water driven off at 230° Fahr.	6 8
Volatile matter exclusive of water	40 8
Fixed carbon	47 6
Ash	4 8
	100

	ft.	in.
105. Shale	0	6
106. *Coal*	0	4
107. Shale and sandstone badly seen	18	0
108. Sandstone containing nodules	2	6
109. Shale	2	8
110. Grey shaly limestone	0	3
111. Shale	2	4
112. *Coal*	0	4
113. Grey shale	0	1
114. *Coal*	0	1
115. Grey shale	3	6
116. Soft grey sandstone	0	3
117. Shale	0	3
118. Nodular limestone	1	8
119. Sandy grey shale and limestone	7	6
120. Sandy shale, very carbonaceous below, with large shells	0	8
121. Earthy *coal*	0	5
122. *Coal*, with calcareous bands interstratified	0	6
123. Grey sandy shale	1	2
124. Carbonaceous shale	0	2
125. Sandy shale	0	8
126. Carbonaceous shale and a little *coal*	0	8
127. Sandstone, shaly in parts	16	0
128. Hard shale with layers of coal	0	6
129. *Coal*, good	1	1
130. Shale, with limestone nodules	3	6
131. *Coal*, good	0	3
132. Carbonaceous shale	0	6
133. Shell marl	0	2
134. *Coal*	0	2½
135. Shell marl	0	2½
136. *Coal*	0	6
137. Shell marl	0	1
138. *Coal*	0	3
139. Shale	2	6
140. *Coal*,[1] good	0	8
	361	6

The beds are very similar to those of Mach in the Bolán, as may

[1] An analysis of the coal from this seam by Mr. Mallet gave—

Water driven off at 230° Fahr.	3	0
Volatile matter exclusive of water	42	8
Fixed carbon	46	1
Ash	8	1
	100	

be seen by comparing the section just given with that measured by Mr. Griesbach.[1] It is remarkable that fossil shells, usually rare in the olive shales, should occur in both localities in abundance in the beds associated with the coal.

Resemblance to Mach beds.

In the hills to the south, the beds resting upon the shales associated with the coal dip southward at a low angle, and consist of shales with intercalated limestones. Three-quarters of a mile to the north more coal outcrops are seen, probably the same seams repeated by a roll of the strata. Again the beds are vertical or nearly vertical. At this place one seam was traced, and found to thin out within a short distance, about 350 yards, from a foot in thickness to a mere layer or two in carbonaceous shale.

Hills south of section.

A few miles from Sháhrág, on the road to Harnai, the road descends to a valley, chiefly cut through subrecent conglomerate. East of Sháhrág, although the valley-like depression that marks the outcrop of the olive shales continues, the outlines are less regular. The shales appear at intervals. In this direction they are much variegated with different colours,—brownish-red, yellowish-brown, &c., and some are claret red. Beds of varying thickness, from a foot to twenty or thirty, come in, composed of hard grey and olive sandstone, fine grained in general, sometimes enclosing fragments of clay, and well stratified. These beds weather into angular blocks. One band of limestone is seen, weathering of a buff colour, and abounding in large nummulites (*N. obtusa* and other species). In some places coal seams are exposed close to the road; they are always thin, and are probably a continuation of the Sháhrág beds. The dips as a rule are very low, often nearly or quite horizontal.

Rocks of valley between Sháhrág and Harnai.

From Harnai to near Spintangi the same beds are seen, the nummulitic limestone forming an anticlinal ridge to the northward, and the shales occupying the plain

Harnai to Spintangi.

[1] Mem. G. S. I., Vol. XVIII, Pt. 1, pp. 23-26.

traversed by the road. Shortly before reaching Spintangi, the road turns southward, on the bank of a large stream bed, a tributary of the Nári river. To the east of this stream, the limestone forms two or three parallel anticlinal ridges with an east-south-east—west-north-west strike. The most southern of these anticlinals terminates close to the road, and there is a warm spring from which sulphuretted hydrogen is given out at the western end of the ridge. South-west of the base of this hill, a moderate thickness of olive shales is seen, probably 500 to 1,000 feet, resting of course on the limestone of the hill; then the beds become vertical, and a thick band of nummulitic limestone, containing *Nummulites* and *Alveolinæ* in abundance, forms a low ridge running north-west—south-east. The stream cuts its way through this ridge and enters the valley of Spintangi, which is about a mile broad, and composed of vertical olive shales.

Siwalik conglomerate south-west of Spintangi.

The valley of Spintangi runs north-west—south-east, between the ridge of nummulitic limestone just mentioned and another ridge, south-west of the valley, formed of Siwalik conglomerate, exactly resembling the bed found usually at the top of the Siwaliks, and dipping 70° to 80° to the north-east; no nummulitic limestone occurs at the junction; the Siwaliks are in contact with olive shales. The conglomerate abounds in limestone pebbles, many of them black, and resembling the rocks of the upper cretaceous beds; some fragments of hard sandstone, chert, and jasper also occur. The largest pebbles are 5 to 6 inches in diameter.

Peculiar mode of occurrence.

The relations of the conglomerate are not clear. Appearances are in favour of its being the bottom bed of the Siwaliks of this locality, of its resting with pseudo-conformity upon the eocene shales, and of the dip to the north-east being reversed. It is in favour of this view that the next Siwalik beds seen to the southward have a south-westerly dip. There is just a possibility that the conglomerate here, as near Pir Choki, although in contact with eocene rocks, is the highest Siwalik bed, and that the peculiarities of the dip are due to the rocks of the two systems having

been crushed together; but this is less probable than the other view, and appears to be in opposition to the evidence at Tung.

Junction of eocene and Siwaliks at Tung.

At Tung, 12 miles south-east of Spintangi, and on the road from Sibi *viâ* Gandkindaf to Thal Chotiali, the junction of eocene and Siwalik beds is very similar to that at Spintangi, except that no massive band of conglomerate occurs. The "Tung," or defile, is produced by the Bheji river, another tributary of the Nári, which cuts its way through a band of limestone, evidently the same as that seen north-east of Spintangi, but thicker, being probably not less than 1,000 feet thick. The limestone is well bedded, and dips at a very high angle, about 80°, to the south-west; it contians in abundance *Alveolina* and *Nummulites* (*N. obtusa*, *N. spira*, and other species), and it has olive shales both overlying and underlying it. Beneath the underlying shales, as north of Spintangi, limestone crops out at no great distance and forms a high dome-shaped hill, apparently an anticlinal. The eocene shales above the limestone have sandstones intercalated, and are of no great thickness, being apparently much thinner than at Spintangi. They are vertical and are succeeded to the south-west by Siwaliks, reddish-brown clays, and light brown sandstone with bands of conglomerate. A little further to the south-west, the dip of the Siwaliks becomes gradually lower and to the south-westward. Here, again, there is pseudo-conformity between the eocene and Siwalik beds, although the conglomerates of the latter are full of nummulitic limestone pebbles.

Road from Spintangi to Sibi.

From Spintangi to the plain north of Sibi, the road preserves a general south-western direction, almost at right angles to its course from Kach to Spintangi. Siwalik beds are traversed throughout the whole distance, about 20 miles in a direct line. A considerable portion of the route is along the Nári river.

Siwaliks near Gandkindaf.

On this road, after leaving Spintangi and crossing the conglomerate ridge, the Siwaliks dip at first to the south-west, then they become horizontal, and then dip north-

east. This continues for some miles, as far as Gandkindaf. Here there is another of the peculiar valley-like plains, so characteristic of these hills, running east-south-east—west-north-west. On the northern side of the plain, the dip of the Siwaliks is irregular; at Gandkindaf it is to the north-east at a high angle, 60° to 70°, but some distance further east it is in the reverse direction, to the south-west. South of the plain the dip is north-north-east, and the rock is a coarse conglomerate of great thickness. It is probable in this case that the conglomerate is the uppermost Siwalik bed, for beneath it there is a very great thickness of sandstone and clays seen in continuous section, though it is far from clear how the uppermost conglomerate can be here in place, for, as has been just shown, the beds on the opposite side of the plain at Gandkindaf dip in the same direction, north-east, and should consequently be higher. These beds too are overlain by several thousands of feet of Siwalik strata. But it is quite possible that the opposite or south-west dip seen east of Gandkindaf is continued beneath the plain; and if this be the case, all the rocks seen to the northward may roll over, and the conglomerate, although the highest in the system, may come in naturally, or there may be a fault corresponding in direction with the valley.

Section in Nári river.

Below the conglomerate, which is of considerable thickness, the usual light brown sandstones with some conglomerate bands come in with a very steady north-north-east dip of about 20°. This continues for some miles. About Kelat-i-Kila there is more irregularity, the rocks are somewhat crushed and contorted. Gradually lower beds come in, only differing from the upper in containing more clay. Gypsum in flakes is not infrequent. On approaching the plains the beds turn over, and dip southward at high angles[1] in the Nári gorge near the edge of the hill country. The uppermost beds, including the conglomerate, do not appear to be exposed south of the anticlinal.

[1] These are the beds very correctly figured and described by Mr. Griesbach, *l. c.*, p. 15, and Pl. I, figs. 2, 3, and 4.

Throughout all these sections, from Spintangi to Nári bungalow at the entrance of the gorge, and within 7 miles of Sibi, all the beds seen are Upper Siwalik (or Manchhar), not a trace of the characteristic strata belonging to the lower division of the Siwalik system is exposed.

All beds Upper Siwalik.

CHAPTER VII.

NOTES ON THE ROUTE FROM SIBI TO JACOBABAD VIÂ PULAJI AND SHAHPÚR.

The road from Sibi to Jacobabad is near the eastern border of the Kachhi, and traverses flat alluvial ground, mainly desert, throughout, except at one spot close to Mal, and only 12 miles south-south-east of Sibi, where a very low ridge of Siwaliks is crossed. The beds of this ridge consist of sandstone dipping at a very low angle, about 5°, to the northward. Instead of following the direct road, however, between Pulaji and Shahpúr, some of the hills to the eastward were traversed, and visits were also made to the ranges near Lehri.

General course of road.

Siwaliks near Mal.

All the hills along the border of the plain are Siwalik, but nummulitic limestone, easily recognised at a distance by its colour and by the form of the ridges, appears at a very short distance inside the outer range in many places; there is one large hill due east of Nári bungalow, another east-by-south from Mal, another again east of Lehri.

Nummulitic limestone hills to eastward.

At the spot where the Lehri stream leaves the hills, the Upper Siwalik conglomerate is seen dipping at a high angle, 60° or 70°, to the south-west. Here the hills were found to be inaccessible, but some miles further south, the Siwaliks were seen to rest on the nummulitic limestone. At the base of the former are some brightly coloured clays, and above these grey sandstone. Both

Ranges east of Lehri.

apparently and the former certainly belong to the lower Manchhars or Siwaliks.

The nummulitic limestone hill to the eastward is one of the rounded anticlinal ridges so common in this part of the country. It is impossible to say whether Siwaliks recur beyond it or not. It is quite possible that the Siwaliks may extend much further to the eastward, east of Mal and north-east of Lehri, than is represented on the map, the lines in this direction being mere guesses.

Rocks between Pulaji and Dingan.

On the road running to the north-east from Pulaji to Dingan, a halting place a short distance within the hills, near the place where the Ghari stream leaves them, there is much sub-recent conglomerate on the edge of the plain, and the Siwaliks crop out quite unconformably from beneath the newer deposit. They dip south-west at an angle of 30° to 35°, and contain but little conglomerate, the usual massive bed not appearing at the top.

Country east of Dingan.

There is a track eastward from Dingan to Sangsila and Dera Bugti.[1] For some miles along this track the Siwaliks have a low northerly dip. A range of nummulitic limestone, the continuation of that seen east of Lehri, runs some miles north of the road, and near the base of this range the Siwaliks turn up sharply. Here, as near Lehri, it is probable that Lower Siwaliks are represented. The precise line of junction is obscure, the nummulitics appearing to dip north, and there may be a fault. Further east, towards Sangsila, the nummulitics form an anticlinal, and the Siwaliks are seen to rest upon them, but in this direction also, as will be shown in the next chapter, it is doubtful whether the two systems are conformable.

Rocks south of Dingan.

South of Dingan, between the Ghari and Marwar streams, the Siwaliks dip at about 45° to S. 30° W. and consist of soft brown sandstones and brown clays

[1] The stream from Sangsila and Sehéf (Dera Bugti) does not run out of the hills to the northward of Pulaji as represented on the accompanying map, but further south. The stream to the northward is the Ghari.

with perhaps more gypsum than usual, all in the form of fibrous flakes filling vertical or horizontal cracks, precisely as in the Gháziaband Pass near Quetta.

Lower Siwaliks.

From Teghâp, a spot where the Marwar stream runs through a ridge of Siwalik sandstone, a road known as Shekazihád or Ghorbundzihád leads to the south-west amongst Siwalik hills. For a short distance this track passes up the bed of the Marwar stream, then it enters the rocky glen of a tributary from the southward. After entering the tributary valley, lower Manchhars or Siwaliks crop out, and a superb section is exposed. The sandstones, instead of being light brown, are grey with interstratifications of clay, dull and rather light Indian red in colour, more or less variegated and often nodular (marly). Frequently rounded masses of the clay occur mixed up with the sandstone. The conglomerates contain no nummulitic limestone pebbles, but are composed of fragments of sandstone and clay, precisely like the materials of the associated strata. There can be no doubt as to the petrological distinction between these beds and the Upper Siwaliks.

Bed of alabaster.

At the base of the Lower Siwaliks are about 150 feet of red clay and then about 50 more of yellow: the latter is the colour of yellow ochre when weathered, but greyish-yellow or sometimes pale olive with fine violet streaks when freshly fractured. At one place on the top of the yellow clay there is a bed 6 to 8 feet thick of gypsum, finely crystalline, some portions being the purest white alabaster. Fragments of this occur, of as much as a foot in diameter. Many portions, however, are disfigured by black veins.

Nummulitic limestone.

Below the yellow clay is the top of the nummulitic limestone. The section is superbly seen; all the beds dip at about 5°, and there is absolute pseudo-conformity, so far as could be observed, although the Gáj and Nari beds are entirely absent.

In the limestone beds two or three species of nummulite occur, one resembling *N. brogniarti*, another apparently a small form of *N. obtusa*,

and, in a bed just beneath the top, *N. biaritzensis* and *Alveolina.*[1] Casts of large species of *Conus*, of *Lamellibranchiata*, &c., are also found.

The remainder of the route between Sibi and Jacobabad presented no features of interest.

CHAPTER VIII.

NOTES ON THE ROUTE FROM JACOBABAD TO HARRAND IN THE DERAJÁT *VIA* DERA BUGTI.

The general direction of this part of the route is nearly north-east.

Road from Jacobabad to Gandoi.

For about 25 miles from Jacobabad to Goranári, an outpost of the Sind Horse, alluvium is traversed. About 2 miles north of Goranári low rises appear, covered with nummulitic pebbles, and undoubtedly formed, like similar rises near Sibi, of Siwalik sandstones. These beds are seen in section, a little further to the north-west, dipping north at a very low angle, not more than 2°. They are the usual light-brown sandstone and clay. The same beds re-appear here and there on the road to Suri Kushtak and Gandoi, but generally the country is covered with blown sand, sometimes forming hillocks, as in the desert country east of the Indus.

Zen range of nummulitics.

A couple of miles north of Gandoi, the Zen range of nummulitic limestone appears. It is a long, low anticlinal roll, of no great height anywhere, but highest to the westward. It strikes east and west, and extends west nearly to the extremity of the Bugti hill area, not far from Pulaji, and sinks to the eastward into an elevated plain that stretches away to Gandahári hill. Both to the north and south Lower Siwaliks (or lower Manchhars) rest upon the nummulitic strata, and in both cases, so far as was ascertained, in perfect pseudo-conformity, despite the break between the two.

[1] This is the instance of the occurrence of *Alveolina* in the uppermost eocene beds referred to in Chapter I.

North of Gandoi and for a long distance to the eastward, there is a conspicuous ridge of Siwaliks, escarped to the north and sloping to the southward. This ridge is composed of a thick bed of hard whitish marl, and must nearly correspond to the limit between Upper and Lower Siwaliks. The road from Gandoi to Mand presents the following section of the Lower Siwalik group. The beds beneath the marl are thick strata of grey sandstone (often containing irregularly formed calcareous concretions that weather out upon the surface), conglomeratic beds containing fragments of clay and sandstone, clays and ferruginous beds. Some of the conglomeratic beds contain numerous pieces of bone and occasionally these ossiferous beds are highly ferruginous. The clays, which are subordinate and not largely developed, are yellow or red.

Lower Siwaliks near Gandoi.

Towards the base are several brightly coloured beds. There is first a considerable thickness of yellow sandstone with ferruginous bands, then some grey sandstone, and next a bed of ferruginous grit, one of the usual conglomeratic or gritty beds, composed of small clay pellets in a sandy matrix strongly impregnated with iron. Below this again are variously coloured sands—white, purple, and brown,—the colour changing at short intervals. These are just above the nummulitic limestone. The different beds appear not to be constant over any considerable area.

The fossils found in different beds are not the same. Thus one bed, formed almost entirely of rounded sandy concretions, about half an inch in diameter, abounded in fragments of crocodile and tortoise plates, but no mammalian teeth or bones were observed. Some of the tortoise plates must have belonged to large animals.

Fossils vary in different beds.

A dark-coloured rather ferruginous bed abounded in fossil shells, and yielded the species of *Melania, Paludina,* and *Unio* noticed in the third chapter and described in the appendix to this report. Besides the shells numerous bones and some teeth of a *Rhinoceros* were found, but no remains that could be recognised

Mollusca.

as belonging to any other vertebrate. It is of course possible that some of the bone fragments may have belonged to another mammal, but all the teeth found were those of *Rhinoceros*. Just above this bed, in soft sandstone, were the remains of what must have been a perfect or very nearly perfect *Rhinoceros* skeleton. The skull had decayed and only the teeth could be taken, but most of the vertebræ were found attached together, and the lower jaw was in place, a circumstance that alone is almost sufficient to show that the animal must have been buried whole.

Rhinoceros, &c.

The road traversed from Gandoi leads eastward for some miles through the Upper Siwalik area, south of the ridge above mentioned as occurring close to the boundary between Upper and Lower Siwalik beds. The road turns northward and passes through this ridge just before reaching a camping ground called Duzd Kushtak[1] on the margin of the nummulitic limestone rise, here a very low, almost flat, anticlinal roll, the summit of which is a wide open plain known as Dasht Goran (plain of wild asses). The lowest beds of the Lower Siwaliks at this spot comprise ferruginous bands, much resembling laterite, and alternating in places with white sand. The bottom bed is ferruginous, and consequently easily traced in the sections on the sides of ravines, &c. Beneath it are perhaps 50 feet of rather shaly limestone, slightly nodular and containing a small nummulite, apparently *N. ramondi*. Below this limestone are several hundred feet of the usual pale olive nummulitic shale, bands of it in this case, however, being reddish-brown or coffee-coloured. With the shales a few thin beds of impure limestones are intercalated in places (in one locality these were found to abound in *Bryozoa*), and beneath the shales there is thick limestone, forming the surface of the anticlinal rise to the northward, the continuation of the Zen range. Some of this limestone abounds in *Orbitoides* (probably *O. dispansus*), a form with a prominent central boss; many of the individuals are very small.

Rocks near Duzd Kushtak.

[1] A little north of the spot where the name is printed on the map.

Pseudo-conformity of Siwaliks to Nummulitics.

The boundary between Siwalik and nummulitic beds was followed for 8 or 10 miles to the eastward from Duzd Kushtak, and could be seen for nearly as many more, the rocks being perfectly distinguishable for many miles in the clear atmosphere. The boundary was also examined for 4 or 5 miles to the westward of the same place. Throughout the whole distance there appeared to be absolute conformity between the two systems, and this was unusually well seen, because of the uppermost nummulitic bed being a band of limestone only 50 feet thick in general. In no single case does this limestone appear to be worn through. It varies in thickness, but the variation is probably due to differences in the original deposition, not to denudation. Some change must take place between Duzd Kushtak and Gandoi (time did not permit of a complete examination of the intervening tract), because no shales are seen beneath the uppermost nummulitic limestone at the latter locality, but there can be very little doubt that the limestone band is much thicker there.

Siwaliks north of Zen range.

To the north of the nummulitic anticlinal, near Dera Bugti, precisely the same beds appear as to the south. The same olive and coffee-coloured shales, capped by a band of nummulitic limestone, are seen underlying the Siwaliks, which again are similar in character to their representatives to the southward.

Seháf near Dera Bugti.

The Seháf, or valley-like plain in which Dera Bugti, the chief and indeed only town of the Bugti tribe, is situated, is a flat extending for a long distance east and west between the nummulitic limestone ranges of Traki to the north and Zen to the south. The average breadth of the plain is 4 to 5 miles. The surface is thickly covered with a sandy deposit, resembling some forms of alluvium, and derived in great measure from the washing down of sand and clay from the neighbouring hills, partly, also, in all probability, from materials transported by wind.

The beds of the Traki range north of the Seháf are much more disturbed than those of the Zen anticlinal to the south. Against each range there is a fringe of Siwaliks, those to the north of the plain

dipping as a rule at far higher angles than those to the south. South-west of Dera, however, the dips in the Siwaliks are high. East of Dera the Siwaliks north of the valley are nearly or quite vertical, whilst on the south side the dips are very low indeed. Fifteen or sixteen miles to the eastward, near Loti,[1] the Siwaliks terminate, the hard bands of grey and whitish sandstone and white marl forming cliffs, whilst the softer underlying sands and ferruginous beds at the base of the system crop out in the plain.

Conglomerates of Dera valley.

The uppermost Siwalik conglomerates, which attracted Vicary's attention,[2] are well developed throughout the north side of the plain, but are ill seen or wanting to the southward. Altogether the whole thickness of the Siwaliks in the Seháf from top to bottom, including both the upper and lower subdivisions, does not appear to be more than 1,500 to 2,000 feet, and this thickness, with the exception of the upper conglomerate, is mainly composed of Lower Siwalik beds, at all events to the south of the valley, where grey sandstones are found throughout.

Fossil vertebrata, &c.

Fossils were only found in the lowest 500 feet or rather more. Mammalian bones were obtained from two localities; a third, not examined, is said to occur near Loti, and it is probable that remains of vertebrata occur throughout the lower portions of the beds. One of the localities observed was Kumbi, about 12 miles west-by-south from Dera, and a place already recorded by Vicary. Here the same *Paludina* and *Unio* bed occurs as at Gandoi (it was noticed in both places by Vicary), and some *Rhinoceros* molars were obtained from it. A few other teeth were also found. The other locality was 7 or 8 miles south-east of Dera. Here, in a sandstone bed, *Mastodon*[3] remains abounded. In other beds of the neighbourhood remains of *Rhinoceros*, *Dinotherium*, a huge *Hyopotamus*, and

[1] By mistake this name has been printed as Lot on the accompanying map.
[2] Q. J. G. S., 1846, Vol. II, p. 262.
[3] Mr. Lydekker informs me that all the teeth brought away belong to *Mastodon angustidens*.

an abundance of crocodile, garial, and tortoise bones and plates were found.[1]

Apparent conformity between Siwaliks and Nummulitics.

There is the same appearance of perfect conformity between nummulitic and Siwalik beds along the north boundary of the Zen limestone ridge, as there is to the south. The only possible exception is near Kumbi, where the uppermost limestone band, that overlying the olive and coffee-coloured shales, becomes much thicker, and it, instead of the lower limestone, forms the surface of the Zen range, precisely as takes place to the southward, near Gandoi. The appearance of unconformity is due to the circumstance that the nummulitics roll about slightly, whilst the Siwaliks crop out in a straight line, apparently unaffected by the minor undulations, along axes differing from that of the main anticlinal, which disturb the nummulitics. But the evidence is very imperfect. North of the valley again, near Sangsila, there is a spot where the Siwaliks do not appear fully to participate in the disturbances of the underlying eocene limestone. The latter forms two great anticlinal rolls at least—one, the terminal portion of the Traki range, the other, to the northward, the great range culminating at Naffusak. The Siwaliks do not run up the intervening valley.[2]

Natural bridge at Sangsila.

A stream, of some size for these almost rainless hills, is fed by a warm spring in the valley north of the Traki range, and enters the plain at Sangsila through a very remarkable natural arch figured in the frontispiece to this paper. The arch is cut through a low ridge of Siwalik conglomerate, which here dips 50° to 60° to the south. There is a pool of water under the arch, which rises about 40 feet above the water, and is perhaps 30 feet wide, and 50 or 60 in length. It is rather curious to conjecture how

[1] Owing to the great difficulties attending the carriage of heavy specimens, very few except teeth and fragments of jaws, were brought away. These localities in the Bugti hills are well worthy of more extended search, the remains being, as has been shown, of much greater geological antiquity than those obtained from the typical Siwalik beds.

[2] Only a hurried visit could be made to the locality, quite insufficient to show whether there was real unconformity.

such an aperture can have originated, but it was probably formed on a curve of the stream, which looks as if it had formerly cut its way through the conglomerate ridge a little further to the westward.

Route from Dera to Harrand.

The route followed left the Seháf plain close to Dera, and passed by Maráo and Siáh Tank to the great elevated plain known in part as Sham. This plain was crossed from west to east, and from its eastern extremity the track led down the course of the Cháchar stream to the plain of the Deraját, near Harrand.

Hot spring supplying Dera.

Immediately after leaving the plain near Dera, the road to Maráo passed through a narrow gorge in the nummulitics, amongst which rises a warm spring impregnated with sulphuretted hydrogen as usual, though not so strongly as in most cases. This is the spring that supplies Dera Bugti with water for irrigation. Beyond the gorge the path runs along an east and west valley, a synclinal trough of nummulitic limestone. No Siwaliks appear, nor were any observed to the north-east until the low ground was reached on the border of the Derajāt.

Plain of Maráo.

The valley traversed opens into the Maráo plain, a flat expanse, resembling alluvium, 8 miles in length by 2 or 3 in breadth, without any outlet. The limestone beds of the surrounding hills dip towards the plain from all sides. The water that falls as rain (not a large amount) doubtless sinks into the limestone, and re-appears as springs. Like some similar plains of smaller size on the Khirthar range in Sind, Maráo is highly fertile, and much wheat is grown without irrigation.

Greatly increased thickness of Nummulitic limestone above shales.

The road from Maráo to Siáh Tank leads through valleys in the nummulitic limestone. The olive and coffee-coloured shales appear in places, but the limestone overlying them must be that forming the hills north of the Seháf, and several hundred feet thick. This limestone again must be identical with the much thinner band seen in the hills south and south-east of Dera Bugti, and which at Duzd

Kushtak is only about 50 feet thick. The question arises whether the great difference in thickness can be due to denudation, or to the bed having been originally much thicker to the northward. The latter is certainly the more probable, for had the limestone bed near Duzd Kushtak suffered from denudation, it would in all probability have been removed altogether in places before the deposition of the Siwaliks; and this, so far as could be ascertained, is nowhere the case.

Gypsum bed in shales.

In the olive and coffee-coloured shales near Siáh Tank is a bed of gypsum 10 to 15 feet thick. Siáh Tank is a ravine running through the range of hills that forms the southern border of the Takráo plain, a western prolongation of the Sham. In this ravine is one of the usual warm springs.

Hills south of Takráo plain.

From a hill called Kirdári, one of the ranges just mentioned, the geology of the surrounding country can be well seen. The hill and others forming the range south of Takráo plain consist of a lower band of nummulitic limestone underlying the olive and coffee-coloured shales. From beneath this lower limestone band a great thickness of olive shales crops out and forms the extensive plains of Takráo, Sori, and Sham, called collectively on maps the Sham plain.[1]

Sham plain.

The plain is, of course, undulating and destitute of soil. It is very barren, no bushes or trees occurring, except in the hollows near watercourses. The shales of the plain are usually, where weathered, of some shade of olive, but when freshly broken, they are often darker and sometimes slaty. They break into minute flakes, with lustrous, silky surfaces in many cases. In the mode of fracture into small flakes, and in not decomposing readily, with the result that the surface is generally infertile, there is much resemblance between these shales and those of the Talchir subdivision of the Gondwána system. Bands of ferruginous brown sandstone, thick and thin, are intercalated with the shales in places, and in one instance some limestone of the same colour, abounding in *Nummulites leymeriei* and

[1] On the accompanying map the western portion is called Siáh Tank plain.

one or two other species, was found associated with the sandstone. This limestone is identical both in character and position with that seen at the base of Takátu mountain near Quetta.

The watershed between the Sori and Sham plains is a great gravel flat, probably of detrital origin, and the highest part of the tract. It is cut into from each side by the heads of watercourses.

Hills north of Sham plain.

The hills to the north of the Sham plain are formed of beds overlying those of the plain itself, precisely like the hills to the southward. The angle of dip varies, the direction is to the northward. The rocks are thin limestone bands intercalated amongst marls and shales, some of the beds being highly fossiliferous and abounding in various Lamellibranchs, Cones, *Nautili*, &c. In the plain north of the range the dip is north at first, then south. Here Nummulites abound, whereas in the lower beds of the Sham plain fossils are rare.

Khúp range.

North of the plain just mentioned is another range running nearly east and west, and known as Khúp. This range consists of an anticlinal of the beds at the base of the lower olive shales, here containing more ferruginous brown sandstone than to the southward.

Hills and plains seen from Khúp range.

From the top of the Khúp range there is a fine view over various plains and ridges beyond. First comes the Phailawar plain, very similar to that of Sham, except that it is not quite so barren. It appears to be formed of the same olive shales. The Siáh Koh to the north of this plain has the appearance of being another anticlinal of lower eocene rocks. Three other ranges seen further to the north-west have much the same appearance. Beyond all these is a higher range, called Jándrán, which looks like nummulitic limestone.[1]

The hills south of the eastern portion of the Sham plain are almost

[1] The continuation of this ridge was examined by Mr. Ball and found to be composed of that rock.

entirely composed of olive shales with a southerly dip of 10° to 15°, and sometimes more. Some shaly limestone occurs in the middle of the shales, 'and appears to be the same as that forming the surface of Gandahári hill further south, evidently the lower of the two limestone bands seen in the Zen range south of Dera Bugti. In the section south of the Sham plain this lower band cannot be more than 100 feet thick. Some coffee-coloured shale and a band of gypsum occur beneath the limestone. Above it there is no well-marked band of limestone at all; though there is a considerable thickness, 500 feet at least, of olive and coffee-coloured shale, the olive tint passing at times into bluish-green, and at others becoming dark and slaty.

Ranges south of Sham plain.

Upon these eocene beds and forming a great range of hills known as Dab to the north of Gandahári, there is a considerable thickness, 700 feet or more, of some beds quite distinct from any seen in the Bugti hills to the westward. These beds consist of sandstones with subordinate beds of clay, conglomerate, &c.; the most conspicuous strata are earthy brown (greyish-brown) sandstones of great thickness, and with these are associated, especially towards the base, dull reddish-brown sandstones, reddish and yellowish-brown clays, some highly ferruginous bands, and a few layers, hard or soft, stained of a black colour, apparently by manganese. One extraordinary argillaceous sandstone, close to the base, has a strange resemblance to a volcanic rock, being mottled dark green and red; another phase of the same rock apparently might almost be classed as laterite. The beds of the hills composed of these rocks are horizontal, or nearly so, so that the upper portions are formed of the thick brown earthy sandstone; whilst towards the base the variation in colour produced by the thinner bands of highly coloured rock is very remarkable and peculiar; none of the beds are typical of the Siwalik system, and there is a wide difference between them and the Lower Siwaliks that rest on the eocene beds only 15 or 20 miles further east. These peculiar sandstones of the Dab hills are, in all probability, Upper Nari, as

Nari beds near Gandahári hill.

they resemble the strata of that group in Sind in appearance as well as in position.

Changes in strata to eastward.

It is curious to find that the Nari group, wanting throughout the east and west ridges of the Bugti hills, re-appears where the general direction of the ranges turns north and south once more, as in Sind. Unfortunately the oligocene limestone at the base of the Nari does not occur to the north-east. The uppermost eocene limestone, too, appears to have vanished entirely, and the Nari beds rest immediately upon the olive and coffee-coloured shales, although the limestone was well developed only 15 miles further west. Notwithstanding this, there is the same appearance of conformity, although the intercalation of the Nari beds between two systems that were in apparently conformable superposition a few miles to the westward, shows how fallacious these apparent conformities are.

Sulphur locality.

Gandahári hill.

Sulphur is said to be found south of Gandahári hill, in small quantities, amongst whitish beds.[1] Gandahári hill was not examined, but the view of it from a distance shows clearly that it is an anticlinal of eocene limestone, a continuation of that south of Dera Bugti, but much higher.

Cháchar Pass.

The bed of the Cháchar[2] stream, along which the road leads from the Sham plain to Harrand, is nearly coincident in position with the change in the strike of the rocks. To the southward, this strike is south-west—north-east, gradually passing into east and west; to the north the axis runs north and south, and the Sulemán range commences. North of the Cháchar Pass is the high ridge called Mári, in places 5,000 feet above the sea. This ridge extends for 20 miles from north to south, and consists of an anticlinal roll of beds inferior in position to the olive shales of the Sham plain,

[1] Probably nummulitic, as are the shales in which the mineral is found further north near Mangrotha.

[2] By mistake printed Cachar on the accompanying map.

and close to the base of the eocene system. South or south-east of the Cháchar is a much smaller hill called Behisto, also an anticlinal ridge, and composed of the same beds as Mári. These beds are chiefly hard, rather coarse brown sandstones, weathering ferruginous brown, some of them purplish, occasionally with red spots on the fresh fracture. With the sandstones is intercalated a band of limestone breccia containing nummulites, the same rock as is found near Quetta.

Behisto hill.

From the top of Behisto, there is a fine view of the tertiary beds extending along the border of the hills to the southward, towards Gandahári. The strata are evidently a continuation of those traversed to the eastward by the Cháchar stream.

Tertiaries seen from Behisto.

In the stream bed between Mári and Behisto, the shales and sandstones are bent into a synclinal, turned on end, hardened and changed into the peculiar phase seen west of Quetta and in Makrán.[1] The hardening and alteration of these beds is probably connected with the change of strike.

Alteration of rocks in Cháchar stream.

Further down the Cháchar, after passing the end of Behisto, olive shales come in above the sandstones, at first with varying angles of dip, subsequently dipping about 45° to east or east-by-south. These shales here form the whole eocene system, with the exception of the sandstones at the base. Nowhere throughout the system is there a band of limestone more than 20 feet thick. This remarkable absence of nummulitic limestone continues for at least 50 miles to the northward, along the west flank of the Sulemán range.

Eocene beds in Cháchar.

A few thin bands of limestone do, however, occur here and there in the Cháchar section, and the most conspicuous of them is probably a continuation of the band forming the surface of Gandahári hill, and of part of the Zen range; but the thickness in the Cháchar Pass is considerably less than to the south-west. This limestone band forms the crest of a low ridge running nearly north and south, and seen for many

[1] Said by Mr. Griesbach, as already mentioned, to resemble the "Flysch" of the Alps.

miles to the southward from the top of Behisto. The ridge is rendered conspicuous by the occurrence, just beneath the limestone, of two or three beds of white gypsum, the thickest about 7 feet thick. Above this limestone there is, as to the south-west, no great thickness of shales before the top of the eocene is reached. There is again, as near Gandahári, no limestone above these shales.

Sandstone blocks in tributary of Cháchar.

Just above a spot called Toba, close to the place where the ridge formed by the limestone and gypsum beds crosses the Cháchar, a stream coming from the flanks of Mári to the westward brings down large masses of hard white sandstone, sometimes speckled with brown, together with some fragments of a fine grained sea-green sandstone, also very hard. A few fragments of the last were also seen in other tributaries. The white sandstone is evidently the same as that seen in the Kaha stream further north, and referred to the cretaceous system, and the ravine from which the fragments are derived must evidently cut more deeply into the beds below the eocene than the Cháchar stream itself does.

Gravel slope.

West of Toba all the ground from the foot of Mári to the nummulitic ridge with gypsum beds consists of a great plain of gravel sloping down from the main range to the westward. Some of the fragments are subangular, others rolled. All appear to be derived from the brown sandstones of the lower eocene, and many are covered with a ferruginous glaze.

Nari beds in Cháchar Pass.

It has already been mentioned that the top of the eocene system in the Cháchar section is not far—a few hundred feet at the most—above the ridge of nummulitic limestone and gypsum. The next beds above the eocene shales are the same as those already mentioned as occurring north of Gandahári hill and as belonging, in all probability, to the Nari system. The rocks on the Cháchar are precisely similar to those near Gandahári; earthy brown sandstones above in very thick beds, with some intercalations of sand and sandy clays and, towards the base, deeply coloured sandy and argillaceous beds, ferruginous, brown and black predominating. No trace

of oligocene limestone can be detected. The dip in the Nari beds is lower than in the eocene, and, except at the base, does not exceed 35°.

The thickness of the Nari beds is not very great. They are succeeded, to all appearance quite conformably, by Lower Siwalik strata, grey sandstones, Indian red clays and conglomeratic beds, with the included fragments entirely composed of marls, sandstones, and clays, similar to those of the associated strata. No trace of Gáj beds could be found. The dip gradually decreases to the eastward; it is 30° towards the base of the Lower Siwaliks, but only 10° to 15° two or three miles further east.

Lower Siwaliks.

Conglomerates with nummulitic pebbles, characteristic of the Upper Siwalik beds, appear in the bed of the Chácbar about half way between the places where the Karagáni and the Kumbi, two minor affluents, enter that stream. Towards the plain of the Deraját the dips do not exceed 10°. Either the massive uppermost Siwalik conglomerate is not well developed here, or it may be concealed beneath the alluvium of the Deraját plain; it re-appears a few miles further north.

Upper Siwaliks.

CHAPTER IX.

NOTES ON THE SOUTHERN PORTION OF THE SULEMÁN RANGE FROM HARRAND TO MANGROTHA.

To the west of Harrand an excellent section of the rocks composing the Sulemán range is exposed in the Kaha stream, which cuts a deep gorge from sdie to side of the chain between two high masses, one called Mári, to the south, and the other, known as Dragal, to the north.

Section in Kaha Stream.

Marching to the westward from Harrand, a well marked ridge of the usual coarse, uppermost Siwalik conglomerate is seen along the border of the alluvial plain. The Siwalik rock dips eastward at 45° to 50°; outside of it (between it and

Siwalik conglomerate.

the alluvial plain), and resting unconformably on its upturned edges, are the usual post-tertiary gravels, themselves cemented into a conglomerate.

The thickness of the Upper Siwaliks is not great. Just beneath the conglomerates of the outer ridge light brown sandstones with conglomeratic bands prevail, but some grey sandstones are intermixed with them, and in the conglomerates, together with pebbles of nummulitic limestone, are fragments of soft sandstone. The line between Upper and Lower Siwaliks, here as elsewhere, is drawn where the nummulitic pebbles, characteristic of the former, first make their appearance, but the division is somewhat arbitrary, the two stages passing into each other. The Lower Siwaliks are thicker than the Upper, and consist, as usual, of grey sandstones, of the typical conglomeratic beds, containing soft sandstone and clay fragments, and of a few interstratifications of red sandy clays.

Lower Siwaliks.

The change from the Lower Siwalik to the Nari group is more abrupt, though no unconformity can be traced. Instead of grey sandstone, massive brown sandstone crops out, with grits or fine conglomerates, light brown or whitish in colour, containing subangular fragments of quartz. Brown and reddish argillaceous beds are also interstratified. There are, as in the Lower Siwaliks, some conglomeratic beds with sandstone and marl fragments. Towards the base the usual highly coloured beds occur, as on the Cháchar stream and near Gandahári hill.

Nari group.

To the Nari beds succeed the olive beds of the eocene, precisely as on the Cháchar. The thin band of limestone, with the conspicuous beds of gypsum beneath it, appears here also. The shales occupy the valley of the stream for about 3 miles; they extend to the foot of the main range, and have scarcely any limestone interstratified. The dip to the eastward gradually diminishes from 50° to about 20°. At the main range the hard brown sandstones to which its existence is evidently in great measure due, and of which its surface is largely composed, crop out from beneath the olive shales, the two being interstratified to some extent, and occasional beds

Eocene beds.

of shale being found in the sandstones. Where these hard sandstones crop out, the gorge cut by the Kaha stream commences, and for a considerable distance the river traverses the same beds, which are clearly the same as those seen at the base of the eocene on the Cháchar.

Whitish sandstone probably cretaceous.

The next strata in descending order consist of hard whitish coarse sandstone and grits, well bedded, and dipping about 15° to the eastward. These are doubtless the rocks of which fragments are seen in the tributary that joins the Cháchar near Toba. Some are pale greenish or bluish-green in colour; others purplish or speckled with purple or brown, but the majority are very pale coloured, almost white. A few infrequent bands of shale occur, mostly dark coloured. These beds appear to be unfossiliferous. As stated in Chapter III, they are probably of cretaceous age.

Hot springs.

Several small hot springs issue, either in the bed of the stream or just above it, amongst these sandstones. All emit sulphuretted hydrogen, like the springs in the nummulitic limestone of Sind and Baluchistan.

Cretaceous limestone.

After traversing a thickness of probably not less than 1,500 feet of the whitish sandstones, limestones are reached, very dark in colour, and rather sandy or shaly. They contain very indistinct fossils, chiefly *Foraminifera*, amongst which no Nummulites can be detected. These limestones gradually pass downwards into calcareous shales, dark grey in colour, often very nodular. Fossils are rare, but two species of *Exogyra* and an *Inoceramus* were found. The fossils are cretaceous.

All beds conformable.

No unconformity could be detected between any of the different groups exposed in the section from Upper Siwalik to the cretaceous limestone shales.

Anticlinal.

The limestone shales are the lowest beds seen. Further westward all the beds roll over and dip west. The surface of the Mári and Dragal hills is formed chiefly of lower eocene sandstone on both slopes; in the Gargandáva valley, to the west of the range, it is probable that only eocene rocks occur.

Section of the rocks seen in the Kaha stream.

a, b, c, cretaceous (a, limestone shale; b, limestone; c, white sandstone); d, eocene; e, Nari; f, Lower Siwalik; g, Upper Siwalik; h, post-tertiary.

Thickness of beds.

The accompanying section shows the general disposition of the rocks. A rough estimate of the thickness of each group is given below :—

		feet.	
Upper Siwaliks	. 2,000 to	2,500	(top not seen).
Lower do.	.	5,000	
Nari	.	2,000	
Eocene	. 8,000 to	10,000	(Of this thickness the bottom sandstones comprise least 1,000.)
Cretaceous,	white sandstone	1,500	
"	limestone and limestone shale .	1,000	(base not seen).

Gathi Nadi.

At Gathi Nadi, 5 or 6 miles north of the Kaha, the outer range is entirely composed of the usual coarse conglomerate. Immediately beneath, grey Lower Siwaliks crop out, dipping eastward about 50°.

Khosra Nadi section.

The Khosra (or Kosah) stream is 6 or 7 miles further north. South of it is seen an instance of the tendency, common in Sind on the edge of the Khirthar range, but rarely observed in the Deraját, for the dip of the Upper Siwalik conglomerates to become lower towards the top, and for them to pass into the gravels of the slope along the base of the hills. But little conglomerate is seen and the Lower Siwaliks appear but a short distance inside the hills.

The section below the conglomerate is very similar to that seen on the Kaha

stream. The Nari beds contain in their upper strata a much larger quantity than usual of reddish or orange brown, deep ferruginous red and yellow clays. There are the usual richly coloured beds at the base. The eocene olive shales, which succeed, present no unusual peculiarity. After passing over them for half a mile, a low ridge is met with, formed, as in the Kaha and Chácbar sections, of the outcrop of some beds of limestone overlying gypsum. The latter here is 25 to 30 feet thick. Below are more olive shales, and interstratified with them in places are a few bands, each 2 to 3 feet thick, of nodular limestone. The dip becomes gradually lower towards the base of the main range, where brown sandstones appear as usual.

Clay used for washing hair.

Amongst the upper olive shales in the Khosra are some clays used by the people of the country for washing their hair, and considerable quantities are dug for carriage to local bazaars, as in Sind.

Rocks in the upper Khosra and feeders.

The section was not examined beyond the outcrop of the lower nummulitic strata, but from a hill a good view was obtained of the upper portion of the Kála Khosra, the principal southern branch. The white sandstone below the eocene is cut into, but no lower bed appears to be exposed.

From a hill on the outer ridge of Siwalik conglomerate, between the Khosra and Choti streams, the ravines cut by the northern branches of the Khosra into the flank of the main Sulemán range are well seen. The deepest gorge is that of the northernmost tributary, called Bagar Khosra; in this some grey beds are exposed, doubtless cretaceous limestone. The stream in question is called Jingar on the atlas map.

Conglomerate unconformable to Upper Siwaliks.

The conglomerate of the outer range north of the Kura stream (about 8 miles north of the Khosra) dips at a low angle to the eastward, and is about 300 feet thick. It rests unconformably at one place on Upper Siwalik sandstone, the conglomerate dipping 15°, the sandstone 30°. The conglomerate appears to pass up into the gravels of the slope,

but is probably uppermost Siwalik, and there is evidently a slight break in continuity between it and the Upper Siwaliks beneath.

Siwalik sandstone on Kura stream.

Below the Upper Siwaliks on the Kura stream are some whitish sandstones, with conglomeratic bands. These beds are intermediate both in character and position between Upper and Lower Siwaliks.

Siwalik anticlinal north of Choti Bala.

A low ridge running for about 12 miles from north to south rises from the alluvial plain to the eastward of the hill country, commencing to the southward at the small town of Choti Bala,[1] on the Choti stream.[2] This ridge is a low anticlinal of Upper Siwalik beds. The dips are very low, not more than 1° to 2° near Choti Bala, but to the northward considerably higher, being as much as 10° near Sakhi Sarwar.

Road to Fort Munro.

The road to Fort Munro, a sanitarium on the Sulemán range, passes by Choti Bala, and traverses the outer ridge, formed of the uppermost Siwalik conglomerate, by the gorge of the Choti river. The Lower Siwaliks, Nari and Eocene beds above the brown sandstones, are ill seen on this road, which passes over a gravel flat, or low slope. There appear remains of two such slopes in this neighbourhood; one higher, and probably more ancient, south of the Choti stream; the other, to the northward, lower and traversed by the road. The Nari group appears to increase in thickness to the northward. A thin band of shaly limestone occurs above that overlying the thick gypsum band, whilst below the latter are some beds of impure limestone, abounding in casts of *Lamellibranchiata* and some *Gasteropoda*.

Section in Choti stream.

The gorge of the Choti stream, which cuts a deep ravine into the heart of the main Sulemán range, lies south of the spur up which the road to Fort Munro passes. Close to the base of the main range, the eocene olive shales occur in the stream, dipping 70° to 80°, but the dip soon becomes lower, and

[1] Not marked in the accompanying map, and in the atlas sheet called Grave Buleel.

[2] The Nongarh, north of the accompanying map, is a continuation of part of this stream to the eastward.

about a quarter of a mile further west, where the white sandstone crops out from below the base of the eocene, the dip is only 30°. Near the bottom of the olive shales, there is much green sandstone, then come the purple and brown sandstones of the lower eocene, then the (cretaceous ?) white sandstones. The latter appear scarcely so thick here as on the Kaha, 25 miles further south-south-east, although they form huge cliffs. The cretaceous limestones crop out in due course, dipping east at about 20°. There is an appearance of local unconformity between the limestones and the white sandstones, but it is probably only oblique lamination, for the limestone and sandstone are interstratified.

Eocene.

Cretaceous.

The upper portion of the limestone, as on the Kaha, consists of dark-grey beds, well bedded, and full of obscure fossils. The shaly lower beds are by no means very fossiliferous, but besides the ribbed Inocerami, similar to those in the Kaha section, a coiled cephalopod with the whorls transversely ribbed was found, several poorly preserved specimens being seen, although but few could be brought away, and those only in fragments. The form belongs to the *Ammonitidæ*, but appears to be allied to *Hamites* or some similar genus rather than to true *Ammonites*. Two species of *Inoceramus* probably occur, one with the ribs broad, very regular and concentric, the other with them narrower, and less regular. Some fragments of stems and indistinct remains of leaves were also noticed.

Cretaceous limestone.

Fossils.

Perhaps lower beds are exposed in the Choti section than on the Kaha. The lowest seen on the first named are less distinctly stratified, and are cut up by joints in all directions. The shales are bluish-grey on the exposed surfaces, dark-grey on fresh fractures.

Lowest beds seen.

Above the stream are cliffs fully 3,000 feet high. The upper 300 or 400 feet are composed of lower eocene sandstones, the remaining 2,500 feet or rather more being

Thickness.

about half white sandstone and half limestone. In the stream bed a small hot spring occurs as usual.

Ascent from Zerádán to Fort Munro.

The road to Fort Munro commences to ascend the main range close to Zerádán, where there is a small bungalow. Near the bungalow, as in the Choti stream to the southward, olive shales are seen, together with a few bands of nodular limestone, both dipping 60° to 70°. A short distance up the slope, there are large quantities of the peculiar lower eocene nummulitic limestone breccia, with *Nummulites* and *Alveolinæ*. Some of the masses appear to be in place, and if so, the bed must be nearly at the top of the lower eocene brown sandstones with which it is intercalated.

The dip gradually diminishes as the hill is ascended, the surface nearly corresponding in slope with the dip of the beds. About 3,000 feet above Zerádán a limestone band containing oysters is seen interstratified in the lower eocene. The same bed occurs in the Kaha section, where fragments are found in the stream bed. A little higher up, the white cretaceous sandstone crops out from below the eocene and forms all the surface of the spur. These beds are cut through, and the underlying limestone exposed in the gorge of the Choti Nadi to the southward as already mentioned, but not in the ravine immediately north of the road. In another deep gorge however, that of the Siri stream, further to the northward, and seen from Fort Munro, the limestone is cut into.

Limestone breccia.

The top of the Sulemán range is flat, and here lower eocene beds again come in. A little knoll, apparently the highest in the neighbourhood, to the south of the road, is capped by the limestone breccia. West of this the dip is westward, and the same breccia re-appears on the road to the fort, and again on a little hill, west of that on which the bungalows stand, the bed apparently dipping somewhat irregularly. Judging by the cliffs at the head of the Choti the limestone breccia, which is, as already shown, near the top of the brown sandstones, is only 300 or 400 feet above the top of the whitish cretaceous sandstones, but there may be some faulting, for elsewhere

the whole thickness of the brown sandstone appears to be more nearly 1,000 feet than 500.

View from Fort Munro.

The hill on which the bungalows of Fort Munro are built is on the western side of the Sulemán range, and commands a wide view over the country to the westward. All the ranges as far as the Jándrán appear to be eocene, and so doubtless are the intervening plains.[1] The western slopes of the Sulemán appear also, near this, to be composed of lower eocene rocks. The portion of the range on which the hard whitish cretaceous sandstones are exposed lies just east of the crest, and extends south, as shown on the accompanying map, apparently without interruption as far as the Kála Khosra stream, and north to beyond Ek Bhai mountain, where this sandstone forms a precipice to the west of the highest peak. To the west of this precipice dark lower eocene beds appear to come in, perhaps, as Mr. Ball suggests, faulted against the white sandstone.

Section on Siri stream.

The Siri stream is a watercourse of some size that traverses the hill country 6 or 7 miles north of the road to Fort Munro, and enters the alluvial plain west of Sakhi Sarwar, a shrine of wide reputation amongst both Mussalmans and Hindus. Along the course of the Siri a road was made by Major Sandeman (now Sir R. Sandeman) to the Luni Pathan country.[2] The road is now abandoned and nearly destroyed by rain and streams.

This route enters the hill country, after skirting the hills west of Sakhi Sarwar for some miles, by a gorge between cliffs 500 to 600 feet high, formed of the uppermost Siwalik conglomerate, here horizontal. West of the ridge formed by these beds there is a sudden change in the dip, and the Upper Siwaliks come in dipping at 30° to 40°. As already mentioned in Chapter III of the present report, there may be some unconformity, but the appearance is chiefly due to disturbance.

[1] This is in accordance with Mr. Ball's account (Rec. G. S. I., Vol. VII, p. 145) of the section traversed a little further north. (See Chapter I.)

[2] This was the road traversed by Mr. Ball in 1874 and described by him in the seventh volume of the Rec. G. S. I., p. 145.

The Lower Siwaliks come in as usual below the Upper, dipping at about 45°. Close to their base is a bed abounding in shells and resembling the shell bed at Gandoi and Kumbi in the Bugti hills. The shells, however, are in this case so badly preserved that it is very difficult to identify them. The commonest is a bivalve very like *Unio cardiiformis* of the Bugti hills, but still more like a *Cardium* in appearance; another looks like *U. vicaryi* of the same bed, and a univalve was seen, apparently a *Paludina.* Some fragments of bones were found, but nothing determinable.

Shells in Lower Siwaliks.

Just beneath is a highly ferruginous bed, one of the usual conglomerates of rolled clay balls, but saturated with iron peroxide, which has segregated in nodules of irregular form, often hollow. Only a few bone fragments, none of which could be identified, were observed in this.

The Nari beds form a steep ridge, the strata dipping at 50°. They come in just below those last noticed. The ridge can be seen for a long distance to the northwards and is higher than any other in the neighbourhood.

Nari group.

The eocene or nummulitic beds are the same as usual, only subordinate thin bands of limestone occurring.

Eocene.

As far north as Sakhi Sarwar, the lower ridges intervening between the main Sulemán range and the alluvial plain of the Indus are formed by the outcrops of the various tertiary beds dipping eastward, as shown in the section of the Kaha stream. But north of Sakhi Sarwar there is a double roll of the strata, a synclinal near the main range, followed by an anticlinal further east, and the fringe of lower ranges is much wider, all the beds down to the eocene inclusive being exposed in the anticlinal.

Double roll of beds north of Sakhi Sarwar.

Ascending the stream that issues from the hills at Sakhi Sarwar, the Lower Siwaliks crop out just inside the first range. The boundary is unusually well seen, and there is no unconformity. North of Sakhi Sarwar, the dip of the uppermost conglomerate in the hills bordering the plain is very high.

Siwaliks near Sakhi Sarwar.

Sakhi Sarwar lies nearly west of Dera Ghází Khán. North of this but one double traverse of the hill country was made from Vadúr (Vuddore) by the Vadúr Pass to the foot of Saronk and back from the Sáonra (Sounhra) Pass by the Sangarh track to Mangrotha.[1]

Traverse of hills further north.

At the entrance to the Vadúr Pass near Vadúr the uppermost Siwalik conglomerate is not seen; the Upper Siwaliks are vertical, striking N. 15° E. They only continue a very short distance, certainly not half a mile, before the whitish intermediate sandstone appears, followed by the grey sandstone of the Lower Siwaliks. All the beds are vertical or dip at a very high angle.

Vadúr Pass.

Quite at the base of the Lower Siwaliks, in a bed similar to that seen in the Siri section, two species of *Unio* occur, one of them ribbed and probably identical with *U. cardiiformis* of the Bugti hills. Associated with these are a *Cerithium*, a *Natica* and a *Cyrena*-like shell. This bed may be estuarine, and possibly indicates the northern extension of the marine Gáj or miocene area of Sind.

Marine or estuarine shells in Siwaliks.

The Nari group appears thin and only continues about 200 yards; it cannot therefore be much more than 500 or 600 feet thick. Beneath it, in the olive eocene shales, there is some brown limestone, like the oligocene Nari limestone of Sind, but evidently of eocene and not of oligocene age, for it contains *Orbitoides dispansus* and a nummulite that looks like a large variety of *N. biaritzensis* or *N. beaumonti*.

Nari.

Eocene limestone.

The nummulitic beds form the axis of the anticlinal; they soon roll over and become horizontal. They continue thus for about 4 miles, then they dip westward. Only a few hundred feet of shales are seen in the Vadúr stream beneath

Anticlinal axis.

[1] In consequence of illness, which finally obliged me to leave the field, the observations were few and imperfect.

the limestone bands associated with gypsum, which are as conspicuous here as further south.

West of the anticlinal, the Nari beds appear better developed than to the eastward, and form a well-marked ridge, higher than any other in the neighbourhood, as they do on the Siri stream. They dip about 35° to west.

Nari beds west of anticlinal.

The Lower Siwaliks then appear and continue for a long distance. They dip at 50° when they first come in, but the dip diminishes to the westward. No shell bed is here seen at their base. The Upper Siwaliks are almost horizontal; they form part of an open plain, covered in general by gravel, and extending nearly to the foot of the main range. It is far from easy here to distinguish between them and the Lower Siwaliks. Pebbles of nummulitic and *Alveolina* limestone occur in grey sandstone, which must be classed as Upper Siwalik, although such grey sandstones, in this country, generally belong to the lower sub-division. It is very possible that further north the two sub-divisions of the Siwaliks cease to be recognisable, and become undistinguishable as they are in Sind.

Siwaliks.

Nari sandstone is well seen near a place called Gurk (Guruk). It dips 30° to the eastward and contains an unusually hard band, as hard as the white cretaceous sandstone.

Nari beds near Gurk.

In the eocene beds near the base of Saronk, there is a considerable increase in the quantity of limestone, compared with the same beds further south. The limestone above the gypsum beds, which continue to occur, is thicker, and there are many more bands intercalated in the shales below. In the Sáonra or Sangarh stream a limestone bed about 200 to 300 feet thick is cut through. This bed forms a distinct and well-marked ridge, continuing for a long distance to the north, and known as the "White range." Through this range there are said to be very few passes, but a good road leads between it and the main range to the Vehowah stream. It is worthy of notice that the

Eocene.

Nummulitic limestone.

band of nummulitic limestone here appearing is in the middle of the system, having shales both above and below it, and is, not like the Khirthar, at the top of the eocene.

Beds of main Sulemán range.

Owing to circumstances the high range of the Sulemán was not visited and the mapping of the beds below the eocene is in great part a matter of conjecture. The brown lower eocene sandstones can be seen from a distance running up the slopes, and the greater portion of the hills appear to consist of the hard white sandstone. In the Lurkán stream, running from the south side of the lofty peak Ek Bhai, and in the Rúkán coming from the north, between Ek Bhai and Mawaiki, fragments of grey limestone and limestone shale, apparently derived from the cretaceous beds, abound. But these fragments are so numerous in the gravels of the surrounding plain that the occurrence of some in the stream bed really proves nothing. Moreover, calcareous grey shale and grey limestone occur in eocene beds a little further north, near the base of Saronk, and fragments derived from them are indistinguishable from those of the cretaceous rocks. Still there is good reason to believe that the cretaceous limestone is exposed in the streams named, in consequence of the depth to which their channels are cut.

On the crest of the Sulemán behind Mawaiki, lower eocene sandstones appear to occur, as well as above the deep gorge of the Rúkán stream between Mawaiki and Ek Bhai.

North of Saronk, the lower eocene strata appear to cover up the older beds, and to form the surface of the range, and in the Saonra Pass, a broad valley that traverses the main range from east to west, no beds are exposed lower than the hard sandstones at the base of the eocene. The pass, in fact, is a low synclinal (or to be more exact, a spot where the anticlinal forming the main range dies out for a short distance), the rock at the surface, throughout a considerable area, being the same massive band of coarse sandstone. To the northward, the beds rise again and form a hill known as Mári, and the Sulemán anticlinal doubtless reappears.

Going down the Sangarh stream, which runs north-east, diagonally to the strike of the beds, the same section is seen as was observed on the Vadúr. Above the eocene system, the Nari beds are well developed and contain much red clay.[1] They dip about 30° to 40°. Again here, as in the Vadúr stream, it is difficult to distinguish between Upper and Lower Siwaliks.

Section on Sangarh stream.

The rocks turn up again about 15 miles from the hills, and are repeated twice, precisely as in the Vadúr stream, by an anticlinal, in which all the tertiary beds crop out down to the upper eocenes. To the south of the stream, the latter, probably in consequence of an increase in the thickness of the limestone, form hills of considerable height.

Sulphur is extracted from eocene beds in two localities near the banks of the Sangarh. One of these places is west of the anticlinal and is callad Swaidko, the other called Galki is only 6 or 7 miles from Mangrotha. In each case, the ore, a mixture of sulphur and gypsum, is brought from the eocene beds at some distance. The mines were not visited.

Sulphur mines.

East of the anticlinal, on the edge of the alluvial plain, no Upper Siwaliks are seen; the ascending section terminates with the Lower Siwaliks. The beds above the eocene dip at high angles.

Siwaliks near Mangrotha.

[1] This shows a resemblance to the typical Murree beds.

PART III.

CHAPTER X.

ECONOMIC GEOLOGY.

Deficiency of useful minerals.

It has become the practice in these memoirs to append a chapter on economic geology, although, in cases like the present, when scarcely any minerals of value are known to occur, and when the examination of the country has been too superficial and partial to afford trustworthy evidence as to the probability of any being found, such a chapter is little more than a confession of ignorance. The few remarks here appended must be considered rather as references to the previous chapters, than as an account of the useful mineral products.

Coal of Bolán and Harnai routes.

Coal.—The only localities at which coal has been observed are Mach in the Bolán Pass and Sháhrág on the Harnai route from Quetta to Sibi. In both places the coal is eocene. A full account of the seams, so far as they have been examined, of the quality of the coal, and of the conditions under which it occurs, was published in the Records of the Geological Survey of India for 1882.[1] The geological features of the localities are described in Chapters IV and VI of the present report. As far as is hitherto known, the seams are much too thin to be profitably mined on a large scale, and there is great doubt as to their being constant in thickness over any considerable area. The quality appears to be sufficiently good for most purposes.

Coal of Luni Pathan country.

The coal of Chamarlang, west of the Sulemán range, and beyond the area examined, was examined by Mr. Ball as already noticed in Chapter I, and appears to resemble that of Mach and Sháhrág in character and geological position.

In connexion with coal the reported petroleum locality of the Mari

[1] Vol. XV, Pt. 3, p. 149.

hills may be mentioned. It is at a distance of four or five days' march to the eastward of Gandkhindaf on the Harnai route to Quetta, and, as stated in the first chapter, want of time prevented a visit to the spot. From the accounts received, however, it is probable that the quantity of petroleum is very small, as it is in some places in the Punjab, and especially one close to Ráwalpindi.

Petroleum of Mari Hills.

Sulphur.—The occurrence of sulphur at several localities just beyond the Sind and Punjab frontier is well known, and some account of the mineral was given by Mr. Ball in the third volume of the Manual of the Geology of India.[1] The most important mines are west of Bágh in Kachhi, and the sulphur is extracted near that town. As already mentioned, time did not permit of a visit to the locality. Another locality is that mentioned in the last chapter, in the Sangarh Pass[2] west of Mangrotha. Here,[3] as already mentioned, the mineral brought to the place where the sulphur is extracted is a mixture of that substance with gypsum.[4]

Sulphur localities.

Bágh

Near Mangrotha.

It is possible that the sulphur may have been derived from the decomposition of hydro-sulphuric acid; this substance (sulphuretted hydrogen) is always emitted by the warm springs that occur so frequently in the hills of the Sind and Punjab frontier.

Another locality, as already mentioned in Chapter VIII, is said to exist south of Gandahári hill, but it is not worked; other places may also occur; indeed it is not improbable that the mineral is rather widely distributed in the eocene beds.

Near Gandahári hill.

[1] Page 157.

[2] This is, I think, the locality near the Sooree Pass mentioned by Mr. Ball. The Sooree or Shori Pass is nearly 20 miles south of the Sangarh. I was told that no sulphur is worked in the Shori Pass, but both Mr. Ball and I had to trust to native information.

[3] I was greatly disappointed at being unable to visit the places whence the mineral was actually obtained, but I was too unwell at the time to leave the main track.

[4] So far as I could learn by enquiry and could ascertain by the character of the country, the sulphur occurs in eocene beds. I could not find any confirmation of Mr. Ball's suggestion in his first notice that the sulphur is of volcanic origin. No volcanic rocks were observed in the neighbourhood.

The process of extraction was seen in the Sangarh Pass at two places, and is of the rudest kind. Two ordinary earthen *garrahs* or *handis* (nearly spherical earthen vessels about 15 to 18 inches in diameter, with a mouth 3 or 4 inches across[1]) are placed vertically mouth to mouth and luted together. The lower *garrah* is sunk in the upper wall or roof of a small furnace or hearth, and in this *garrah* ore is placed. The upper *garrah* is exposed, and when the lower is heated by a fire in the hearth, the sulphur is sublimed, and deposited inside the upper in the form of "flowers of sulphur." This is melted and then cooled again in cakes weighing about a seer (2 ℔) each, the cakes being formed by pouring the melted sulphur into a fragment of a broken *garrah*.

Process of extraction.

Gypsum.—This mineral, as already mentioned, is common in the tertiary rocks. It occurs as thin veins filling cracks in the upper Siwaliks around the Kachhi, and in the rocks which I believe to be of the same age in the Mashalak range west of Quetta. In the latter larger masses of gypsum are said to occur.

Gypsum localities.

At the base of the Lower Siwaliks, in the hills south-east of Pulaj, and north-by-east of Shahpúr, at the western extremity of the Bugti hills, some very beautiful white gypsum, or alabaster, was found in irregular masses, some of them as much as a foot in diameter; some of the masses are perfectly pure white in colour, and quite as well adapted for ornamental purposes as the precisely similar stone that is carved into statuettes and vases at Pisa and other places in Italy.

Gypsum, too, occurs in beds of from 5 to 10 feet in thickness in the eocene beds of the Bugti hills and the eastern flank of the Sulemán range.

The use of plaster made from gypsum, instead of mortar from lime, for building is common in Persia, and I believe in many other parts of Central Asia, as in Afghanistan, where the rainfall is not heavy. Some use has been made of similar plaster at Quetta, the gypsum being

[1] The measurements are given from memory, and may not be exact.

obtained from the neighbourhood of the Gháziaband Pass on the Mashalak range.

Building stones.—The limestones of the cretaceous and eocene systems generally furnish excellent building stone. Some of the upper tertiary sandstones are also well adapted for building purposes, but they are often liable to crumble in exposure. At Quetta the dark cretaceous limestone is used for building.

APPENDIX.

DESCRIPTION OF FRESH-WATER SHELLS FROM LOWER SIWALIK BEDS OF THE BUGTI HILLS

The following species were briefly noticed in Part I, Chapter III. They are very curious and interesting forms, and, although I have rarely attempted to describe fossils, I have been induced to undertake the task in the present instance, because I have some acquaintance with the living species of the same genera now inhabiting India and the neighbouring countries, and because of the peculiar interest attaching to fossil land and fresh-water Mollusca in general :—

1. MELANIA PSEUDEPISCOPALIS, sp. nov., Pl. 1, figs. 1, 2.

Testa pro genere magna, solida, breviter turrita, fere pyramidata. Spira imperfecta; anfr. superst. 3½ *convexi, sensim accrescentes, costis verticalibus fortibus distantibus, in anfr. ultimo superne juxta suturam atque infra medium evanescentibus ornati, et lineis spiralibus elevatis filiformibus distantibus tuberculoso decussati. Anfr. ultimus basi liris spiralibus confertioribus 4—5 ornatus. Apertura ? Long. 1·92; diam. 1·1 poll. angl. Apert. long. circum 1.*

Shell large for the genus, thick, moderately turreted, not elongate, but almost pyramidal. Spire imperfect, about 3½ whorls remaining, which are well rounded, and increase in size regularly. They are ornamented with vertical ribs and raised spiral lines; the ribs are far apart from each other, and appear, so far as can be made out, to vanish above near the sutures, and below the middle of the last whorl; they are nodose where crossed by the spiral lines, which are distant from each other, except around the base of the last whorl, where they are rather closer together. So far as can be judged, there must be on the last whorl 5 or 6 distant raised spiral lines round the upper and middle portion, and 4 or 5, closer together, round the base. The form of the aperture cannot be ascertained, but was probably sub-rhomboidal, as in the recent *M. variabilis.*

Melania pseudepiscopalis belongs, so far as can be judged from the single specimen procured, in which the aperture is not preserved, to the sub-genus *Melanoides*, Oliv. and is most nearly allied to *M. variabilis*, Bens., *M. episcopalis*, Lea, and *M. sumatrensis*, Brot. It is a difficult question how far these species are really separable from each other, and from numerous closely allied forms that have received names from various conchologists. The form that comes nearest to the type now described, of all that I have been able to compare, is one figured in Hanley and Theobald's Conchologia Indica, Pl. LXXII, fig. 5, under the name *M. episcopalis*, Lea. This specimen, which is from North Cachar, differs considerably from the other

forms referred to the same species in the work mentioned.[1] A specimen from Assam in the British Museum, referred to *M. variabilis*, is also very nearly allied to the fossil.[2]

Amongst the figures in Brot's admirable monograph of the *Melaniidæ*[3] the three forms most nearly allied, so far as sculpture is concerned, are Pl. 11, fig. 2, *M. julieni*, Desh., from Tonquin, Pl. 12, fig. 1a, *M. episcopalis*, Lea, from Malacca, and Pl. 13, fig. 1a, *M. sumatrensis*, Brot, from Sumatra. All of these forms, however, have higher and more turreted spires, and the vertical (transverse) ribs in *M. pseudepiscopalis* are more distant. The spiral lines also are differently arranged. The present form, therefore, may receive nominal distinction.[4] No known fossil species appears to be very nearly allied.

The similarity between the present form and the species mentioned of the subgeneric section *Melanoides* is so well marked that there can be very little doubt as to the affinities of *M. pseudepiscopalis*. The living species of *Melania* belonging to the same section are found along the base of the Himalayas, as far west as the Jumna, and perhaps rather further; they occur throughout a considerable portion of the Gangetic plain, and in Orissa, and they abound in Burmah, the Malay countries, Siam, and the islands of the Malay Archipelago, &c. A species has been found in Malabar, and the type is probably represented in Ceylon, but it is wanting throughout the greater part of the Indian peninsula, and is quite unknown in Sind, the Punjab and all Central India.

Two views of the same specimen are given in figures 1 and 2 of Plate 1.

2. Melania gradata, sp. nov., Pl. 1, figs. 3—5.

Testa gradato-turrita, solida, crassa, lævigata. Spirá vix erosa. Anfr. 6. gradatim accrescentes, haud procul a suturâ forte atque prominenter angulati, infra angulum fere cylindracei, lateribus verticalibus planisque, antice concaviusculis; ultimus parum major, infra angulum concavus, subtus convexus. Apertura fere ovata, postice angulata; margine externo postice retro sinuato, antice arcuato. Long. 1·05; diam. 0·5; ap. long. circum. 0·45 poll. angl.

Var. major, minus elata, ovato-turrita. Long. 1·25; diam. circum. 0·75 poll. angl.

Shell turreted, thick, smooth. The spire is high, scarcely eroded at the apex, and composed of six whorls in one or two specimens, five in others, regularly increasing in size by steps, sharply and prominently angulate just below the suture, and nearly cylindrical below the angulation, the sides being flat and vertical in the upper whorls, slightly concave in the lower, especially in the last whorl, which is prominently but bluntly angulate near the suture, then hollow at the side and convex towards the base. Aperture ovate, not preserved entire in any specimen, but raised lines of growth

[1] By Brot (Mart. Chemn. Conch. Cab., Melaniaceen, 1874, p. 89,) these forms are referred to *M. spinata*, Godwin-Austen, but the particular figure 5 of Pl. 72 above noticed is not quoted in Brot's synonymy.

[2] I am indebted to Mr. E. Smith, the Assistant Keeper, for this comparison. He also pointed out to me the resemblance of the fossil to a form of *M. asperata*, Lamarck, from the Philippine Islands.

[3] See preceding note.

[4] It is rather a question of convenience than fact, whether closely allied forms of fresh-water mollusca shall be classed as "species" or "varieties."

showing the form of the lip when the shell was not quite mature are preserved in a few cases, and show that the posterior or upper part of the outer margin was sinuate or curved back for some distance below the suture, whilst the anterior or lower portion was arcuate or curved forward; the base was probably curved back, perhaps sub-canaliculate.

Var. major, Pl. I, fig. 4. Two specimens, rather larger than the rest, differ in having the spire less raised. I think, however, that there is not sufficient evidence to class these specimens in a different species. One of them has spiral sub-distant impressed lines round the base of the last whorl. This may show that it is really a different species, but there are similar lines, though fewer, on one specimen of the smaller form. No such lines, however, occur on those specimens of which the surface is best preserved.

I am unable to find any species of *Melania*, living or fossil, allied to the peculiar type here described. In general form there is some resemblance to the sub-genus *Plotia*,[1] comprising *M. scabra* and its allies, some of which have the whorls angulate below the suture, but the form of the aperture is different. The group *Tiara*, in which the angulation is more marked and the whorls usually smooth, has a much larger last whorl, and a nonsinuate external margin to the peristome. In both these groups the angulation of the whorl is ornamented with spines, and the same may originally have been the case with *M. gradata*. The present species may be allied to the section *Tiaropsis*[3] including *M. winteri* of Java and its allies, or to the peculiar form *M. impura*,[4] Lea, from the Philippines. These have the outer margin of the aperture sinuate and the whorls more or less angulate, but the general form is different, and none have the peculiarly shaped whorls of *M. gradata*.

It is not quite certain, indeed, that the present species was really a *Melania*. The spire resembles that of the curious fresh-water form discovered by Dr. J. Anderson in Yunan, and named *Margarya melanoides* by Mr. G. Nevill (J.A.S.B., Vol. XLVI, 1877, Pt. 2, p. 30, and Vol. L, 1881, p. 155, Pl. V, fig. 1.—Anderson, An. Zool. Res. Western Yunan, p. 891, Pl. LXXX, fig. 5.), but that has the mouth of a *Paludina* and probably, as suggested by Mr. Nevill, is closely allied to that genus, if it does not belong to it.

The typical form of *M. gradata* is represented on Plate 1, figure 3, the large variety in fig. 4, and in fig. 5 the lines of growth are shown.

3. Paludina bugtica, sp. nov., Pl. 1, figs. 6, 7.

Testa imperforata, ovato-conoidea, solida, glabra. Spira conoidea, lateribus convexis, apice obtuso, suturâ impressâ. Anfr. 4 parum convexi, subplanulati; ultimus haud descendens, subtus rotundatus. Apertura ovato-rotunda, obliqua; peristomate haud incrassato, recto. Long. 0·6; diam. 0·4; ap. long. 0·27 poll. angl.

Shell imperforate, ovately conoid, solid, smooth. Spire conoid with the side convex, apex blunt, suture impressed. Whorls about 4 in number, slightly convex or flattened, generally the latter; the last whorl not descending, rounded below. Aperture nearly round, oblique; peristome not thickened, all in one plane.

Brot, *l. c.*, p. 263.
Ibid, p. 288.
[3] Brot., *l. c.*, p. 299.
Ibid, p. 312.

I am disposed to believe that this species is more probably a *Paludina* than a *Bythinia*, because, had it belonged to the latter genus, I think, in a deposit in which most of the specimens of *Unio* occur with the valves united, that some specimens of the univalve would be found with the shelly opercula in place, just as they commonly are in Indian rivers at the present time.

There is no very closely allied form inhabiting India at the present time (the nearest is perhaps *P. crassa*, Hutton), but *Paludinæ* are not characteristic shells, and a dozen similar species, recent and fossil, might easily be selected for comparison. Two specimens, differing slightly, are represented in figures 6 and 7 of Plate I.

4. UNIO VICARYI, sp. nov. Pl. 2, figs. 1—3.

Testa transversim subtriangulari-ovata, ventricosa, inæquilateralis, concentrice striata, extus atque intus radiatim costata, solida, antice rotundata, postice subangulata; margine dorsali postice primum recto, tunc convexo-declivi, ventrali convexo, postice undulato; umbonibus prominentibus, inflatis; valvulis extus antice glabris, medio ac postice liris sulcisque ornatis, omnibus nisi juxta extremitatem posteriorem subparallelis atque oblique (sc. postice) declinatis, ab margine umbonali ad ventralem decurrentibus, anterioribus minoribus, subdistantibus, mediis 3-4 confertioribus, post medium 3-4 multo majoribus latioribusque, postremis nonnullis brevibus in regione posticâ dorsali, a cæteris divergentibus, atque in marginem posteriorem desinentibus; dentibus cardinalibus magnis. Long. exempli majoris 4; lat. ad 2·25; crass. 2·15 poll. angl.

Shell transversely and subtriangularly ovate, ventricose, especially in the middle, thick, inequilateral, concentrically striated and radiately ribbed both inside and outside, short and rounded anteriorly, subangulate at the posterior end. The dorsal margin is straight for some distance behind the beaks, then rather convex; ventral margin convex, rather prominent in the middle in some specimens, undulating posteriorly opposite the terminations of the ribs on the valves. Umbones prominent and swollen. The valves are nearly smooth near the anterior extremity, but all the rest of the surface is covered with straight ribs and furrows; all the ribs except at the posterior end being subparallel, and sloping obliquely and backwards towards the ventral margin. The first (anterior) ribs are small and subdistant, the next three or four, in the middle of the shell, still small but close together, then a few on the posterior portion of the surface, about 4 in number, are much larger and broader, whilst the dorsal portion of the posterior surface is occupied by a few broad short ribs diverging from the others and running directly towards the posterior end. Cardinal teeth large.

This description is chiefly taken from the only specimen in which the external surface is preserved. The measurements of this specimen are given above. The other examples collected are chiefly casts with the inner portion of the shell remaining. The broad ribs on the posterior surfaces of the valves are preserved in all the casts, and appear as well marked internally as externally, but the finer anterior ribs have disappeared inside the shell. A perfect cast of a shell rather smaller than that of which the dimensions were given above measures—length 3·6, breadth 2·2, thickness 1·9 inches.

I am unacquainted with any species of *Unio*, living or fossil, with which this well marked form can be considered as allied.[1]

Only six specimens of this species were collected; in all but one both valves are in position. Many were seen, but the majority were mere casts or too imperfect to be worth bringing away. The species did not appear to be rare. It is named after Captain Vicary, the original discoverer of the deposit containing the curious series of fresh-water shells now described.

In Plate 2, fig. 1, the specimen above mentioned, in which the surface of the shell is fairly preserved, is represented. Figures 2 and 3 are taken from a well-preserved cast with a little of the shell remaining attached.

5. UNIO CARDIIFORMIS, sp. nov., Pl. 3, figs. 1—6.

Testa fere orbiculata, rotundato-ovalis, subæquilateralis, valde radiatim costata, crassa, ventricosa, antice atque postice rotundata; margine dorsali ante umbones concavo, post eos primum subrecto, deinde convexo; ventrali rotundato, valde undulatim corrugato; umbonibus prominentibus, inflatis; valvulis liris sulcisque radiantibus rectis fere æqualibus, postice declinatis, obtectis; dentibus cardinalibus magnis. Long. 3; lat. 2·6; crass. ad 2 poll. angl.

Shell almost circular, much resembling a *Cardium* or *Pectunculus* in general form and sculpture, subequilateral and ornamented with strong radiating ribs, thick, ventricose, the anterior and posterior ends rounded; the dorsal margin concave in front of the umbones, straight for a short distance behind them, then convex, ventral margin evenly rounded, and deeply corrugated, the corrugations corresponding to the termination of the ribs on the valves. These ribs are straight, nearly equal in size and equidistant; all have a considerable inclination backwards as they pass from the dorsal to the ventral margin. The number appears to vary. In the best preserved example (that figured) there are 14, on another only 11 or 12, the posterior extremity of the shell being in this case smooth, though it is ribbed on the other. Cardinal teeth very large.

The measurements of a large specimen are given above. A smaller and less perfect pair measures—length 2·4, breadth 2·2, thickness 1·6 inches. A cast is $2·5 \times 2·25 \times 1·5$.

This and the next species are two of the most remarkable forms of *Unio* ever discovered, and they would probably be made a separate genus by many palæontologists and by some malacologists. There is a slight resemblance between them and certain living American forms, such as *U. plicatus*, Say, and *U. laticostatus*, Lea, but no near connexion. The prominent sculpture formed by the alternating ridges and furrows and the remarkable corrugated ventral margin are exaggerations of the features found in the genus *Cardium*, and rather resemble the peculiar characters of some mesozoic species of *Ostrea*. Some approach to this character is, however, seen in certain intertrappean forms of *Unio* of upper cretaceous age, occurring near Nagpúr.

[1] At first sight it appeared to me that there was a resemblance between both this form and *U. cardiiformis*, and some of the species of *Unio* obtained from the intertrappean (upper cretaceous) beds of Nagpúr and other places in Central India. The same idea occurred independently to Dr. Feistmantel. I was unable to compare the specimens now described with the collection of intertrappean fossils in Calcutta, but although there is a slight similarity between *U. vicaryi* and the intertrappean *U. hunteri*, Hisl. the two do not seem very closely connected.

The cast is almost smooth, the external ribs not being repeated on the inside of the shell except close to the ventral margin.

U. cardiiformis was common at both the places (near Gandoi and near Kumbi) in the Bugti hills, where I found the bed with fresh-water shells, and it was doubtless the species seen by Vicary [1] and taken by him for a *Cardium*. I found either the same or a closely allied form, but poorly preserved, in a bed at nearly the same horizon, close to the base of the Siwalik system, in the Sulemán hills, on the Siri stream, west of Sakhi Sarwar and again in the Vadúr Pass further north. It is possible that the same form was noticed by Mr. Wynne [2] at precisely the same geological horizon in the Kohát district of the Punjab.

As with the other species of *Unio*, the two valves generally occurred together.

Three views of this shell are given on Plate 3, figures 1, 2, 3. Figures 2 and 3 are to some extent restorations, and are intended to show the dorsal and ventral aspects.

5a. Unio cardiiformis *var.* (*vel species distincta*). Pl. 3, fig. 4.

Testa trigono-globosa, crassa, ventricosa, costis validis paucis radiatim ornata, antice rotundata, postice subangulata; margine dorsali post umbones declivi, recto; ventrali rotundato, valde undulato, cæterum similis U. cardiiformi typo. Long. 2·2; lat. 2·15; crass. 1·9 poll. angl.

This is probably only a variety of *U. cardiiformis*, with fewer ribs and a more triangular shape. It would doubtless be classed as distinct by many palæontologists and conchologists, but recent forms of *Unio* are excessively variable, and I should not like to propose a name for the present form without more evidence of its distinctness. Only one specimen (a pair of valves as usual) has been brought away. The anterior portion of the shell has perished, and of this part only the cast remains; in the perfect shell there were probably about 8 or 9 radiating ribs on the surface of each valve.

The shell described is represented in figure 4 of Plate 3.

6. Unio cardita. sp. nov., Pl. 1, figs. 8, 9.

Testa ovata, inæquilateralis, mediocriter ventricosa, crassa, costis validis subconfertis, ab margine dorsali ad ventralem subradiatim decurrentibus oblique atque postice declinatis ornata, antice atque postice rotundata; margine dorsali ante umbones concaviusculo, post eos subrecto; ventrali convexo, valde undulato; umbonibus prominentibus; dentibus cardinalibus magnis. Long. 2·75; lat. 2·1; crass. 1·6 poll. angl.

Shell ovate, resembling a *Cardita* in form and sculpture, inequilateral, moderately ventricose, thick; the surface of the valves covered with strong straight radiating ribs not very close together, running obliquely from the dorsal to the ventral margin and inclined posteriorly in the latter direction. Anterior, posterior, and ventral margins rounded, dorsal margin a little concave in front of the umbones, nearly straight and sloping behind, cardinal teeth large.

The measurements of a large specimen are given above; a small pair measures—length 1·85, breadth 1·45, thickness 1·15.

[1] Q. J. G. S., Vol. II, 1846, p. 264.

[2] Mem. G. S. I., Vol. XI, pp. 61 (165) and 64 (168).

Although this shell, the specific name of which is given on account of its resemblance to the genus *Cardita*, is well distinguished from *U. cardiiformis* both by form and sculpture, the shape being much more ovate and less ventricose, and the ribbing considerably more distant and more oblique, I am far from certain that the two are not varieties of a single form. Only three specimens, a large and a small pair of shells and one cast, belong to *U. cardita*, and the peculiar variety of *U. cardiiformis* last described shows a tendency to a passage, through having fewer ribs than the type. But so well marked a form as *U. cardita* requires nominal distinction at all events, whether connected with *U. cardiiformis* by intermediate links in the same locality or not.

Like its ally, the present species has not, so far as I am aware, any known ally living or fossil.

Two representations of the specimen described are given in figures 8 and 9 of Plate 1.

7. UNIO PUGIUNCULUS, sp. nov., Pl. 1, figs. 10—13.

Testa transversim elongata, pyriformi-ovata, valde inæquilateralis, ventricosa, crassa, anticæ breviter rotundata, subtruncata, posticæ attenuata, demum truncatula; margine dorsali posticæ declivi, fere recto, ventrali convexo, juxta extremitatem posticam concaviusculo, umbonibus prominentibus, inflatis, prope marginem anticum positis, valvula utraque costis duabus, inferiore multo validiore, haud procul a margine dorsali ab umbone ad extremitatem posticam decurrentibus, ornata; dentibus cardinalibus validis. Long. 1·3; lat. 0·8; crass. 0·65 *poll. angl.*

Shell transversely elongate, pyriformly ovate, very inequilateral, ventricose, thick, short and rounded, almost truncate anteriorly, subconical behind, and gradually diminishing to the end, which is cut off, the dorsal margin sloping, almost in a straight line, from the umbones to the posterior extremity, the ventral margin convex throughout the greater part of its length, but slightly concave close to the posterior termination. Umbones prominent, swollen, situated close to the anterior end of the shell, each valve furnished with two ribs near the dorsal margin running from the umbones to the posterior extremity, the inner of the two (that farthest from the dorsal margin) being much the more prominent, and forming, in fact, a division between the general surface of the valve and the hinge area. Cardinal teeth very large and thick.

There is no very near ally of this form living in the peninsula of India, the nearest being species like *U. cæruleus*, Lea, and *U. gerbidoni*, Eydoux. In this case, as in that of *Melania pseudepiscopalis*, much greater similarity can be traced to types existing at present only east of the Bay of Bengal. The closest ally appears to be a form described from Pegu by Mr. Benson under the name of *U. pugio*,[1] and this, again, is said to resemble the Siamese *U. ingallsianus*,[2] Lea. In China, the type is well developed, the extreme form, and one of the best known, and being *U. grayanus*, and some species probably belonging to the same group are found in North America, *e.g.*, *U. nasutus*, Say.[3]

[1] Ann. Mag. Nat. Hist., 3, Vol. X (1862), p. 193. Hanley and Theob. Conch. Ind. Pl. X, fig. 7.

[2] Lea, Trans. Am. Phil. Soc., Vol. X, p. 282, Pl. XXIV, fig. 41. Rv. Conch. Icon., Unio No. 126.

[3] The species named are figured in Lea's Observations; in Küster's Monograph of the genus (Martini and Chemnitz, Syst. Conch. Cab.); and in Reeve's Monograph in the Conchologia Iconica.

U. pugiunculus occurred commonly with the other species described. Several specimens were obtained in fair condition. Both valves, in this and the other species of *Unio*, were almost always found together, showing that the animals must have lived on, or nearly on the spots where they have been preserved.

Three views of different specimens from different directions are given in Plate 1, figures 10, 11, 12. Figure 13 represents a large cast.

To sum up. Of the seven species above described four have no known living allies; one more is not nearly represented by any Indian species, but may perhaps be related to forms existing elsewhere; it belongs, however, to a genus in which there is no great variety and which is not very characteristic. Of the remaining two species, one, *Melania pseudepiscopalis*, is so closely allied to forms now inhabiting Burma and North-Eastern India as to be scarcely separable, and it may be considered as virtually a living species, whilst the last, *Unio pugiunculus*, although clearly distinct from any known living form, is related to a Burmese species, and more distinctly to other forms now inhabiting China and Siam.

Thus of seven fresh-water shells that inhabited the rivers of the north-western Indian frontier in Lower Siwalik times, none are now represented in the surrounding country, five have completely died out, and two have either migrated eastward or have survived to the east and disappeared to the west of India.

It is interesting to note that none of the species described appears allied to the Miocene or Pliocene fresh-water Mollusca of Europe.

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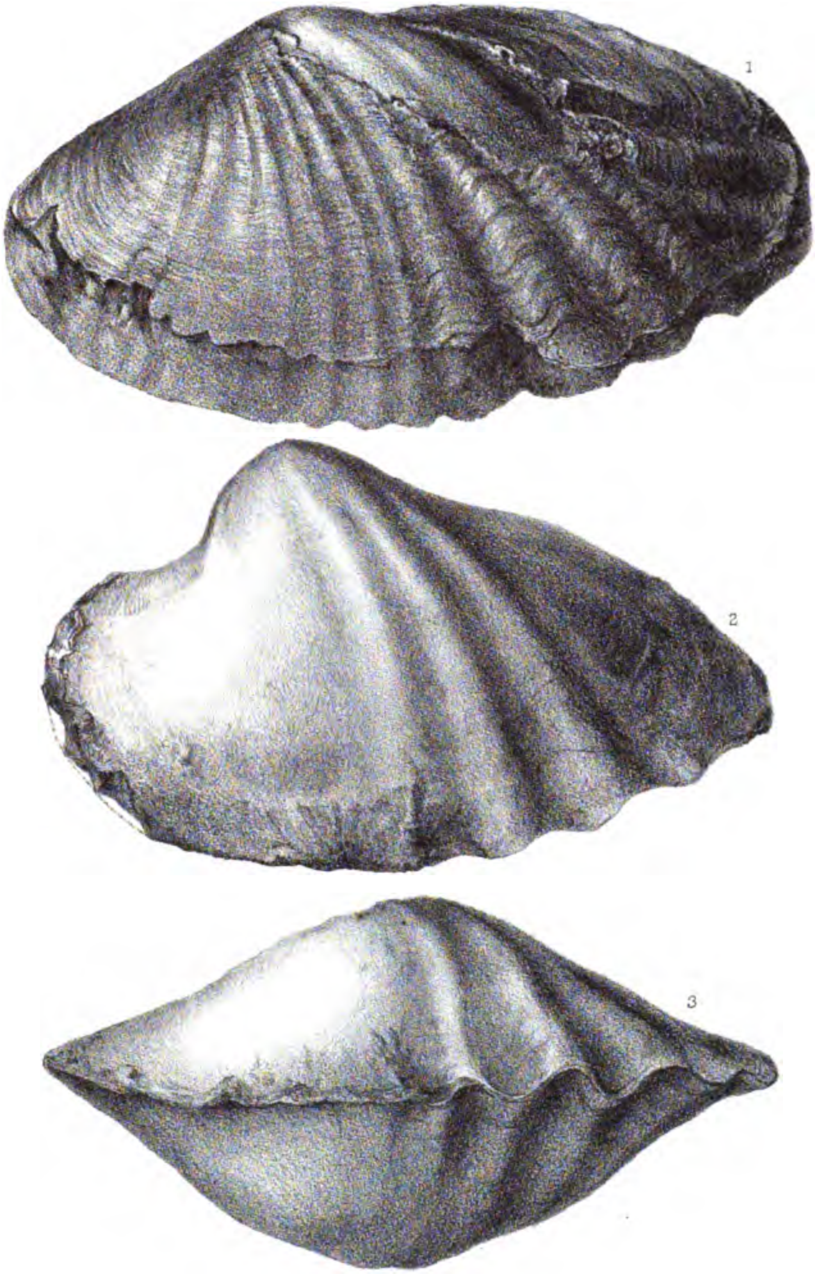
G. M. Herschell ad. nat. lith. Hanhart lith. imp.

LOWER SIWALIK MOLLUSCA.

1-2 Melania pseudepiscopalis, 3-5 M. gradata
6-7 Paludina bugtica, 8-9 Unio cardita
10-13 U. pugiunculus.



G.M.Herschell ad nat lith. Hanhart lith imp.

LOWER SIWALIK MOLLUSCA.

1-3. *Unio vicaryi*.

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FIRST TWENTY VOLUMES

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BY

W. THEOBALD,

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